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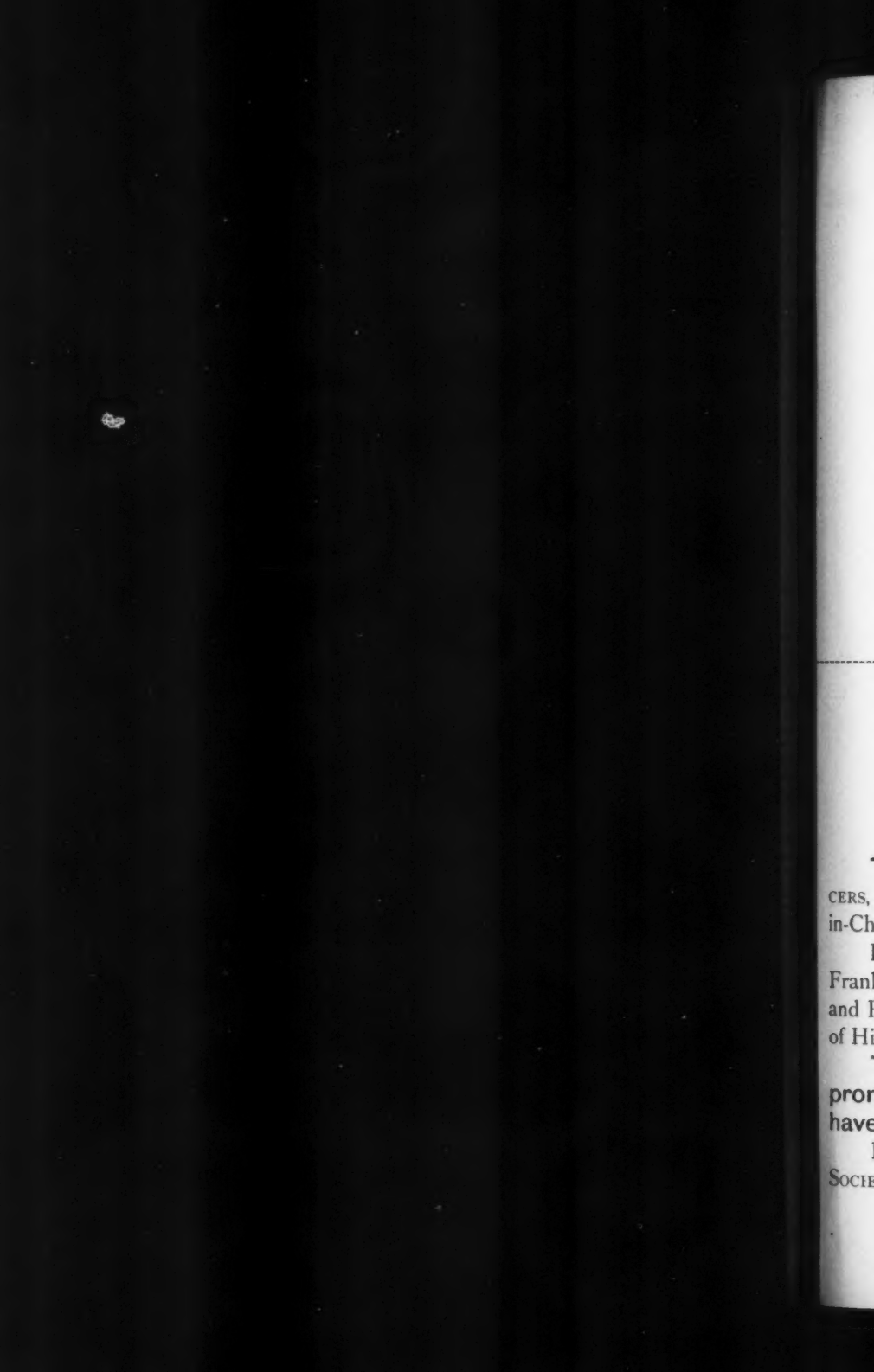

Errata in No. 3, Vol. V.

Page 620—Diameter of crank pins should be:
Forward, 13.5 inches.
Aft, 17.0 inches.
Length of crank pins,
Forward, 17.0 inches.
Aft, 14.25 inches.

Page 636—First set of air-pump cards for *New York*, double strokes should be 24 per minute.

Page 721—The I.H.P. of *Machias* here given is before correction. For corrected I.H.P. see article on trial of *Machias* in this number.

THE ANNUAL MEETING for the election of officers, and other business, will be held in the office of the Engineer-in-Chief of the Navy, on Friday, December 22d, at 8 P. M.

Interesting papers have been promised by P. A. Engineer Frank H. Bailey, U. S. N., on "The Steam Cylinders of Air Pumps," and P. A. Engineer B. C. Bryan, U. S. N., on "Crank Effort Curves of High Speed Engines."

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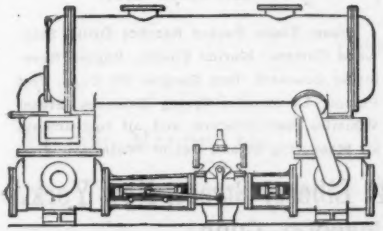

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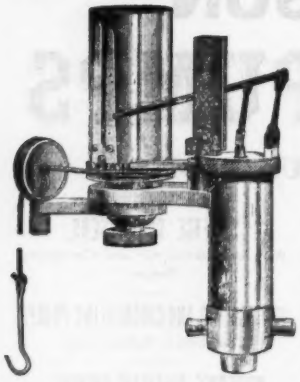

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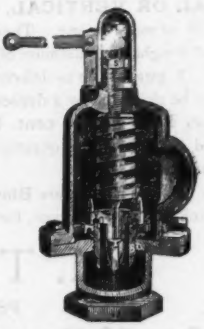

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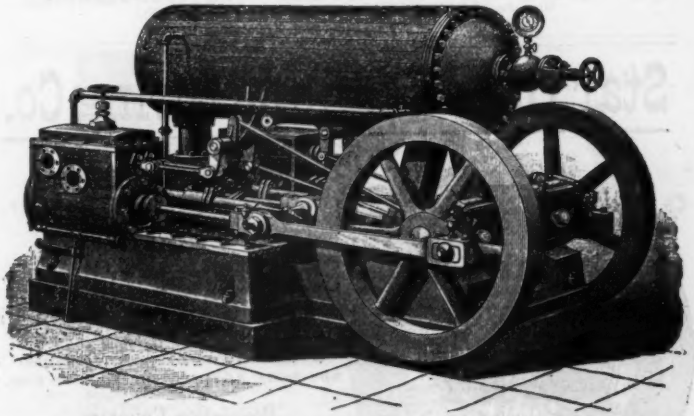

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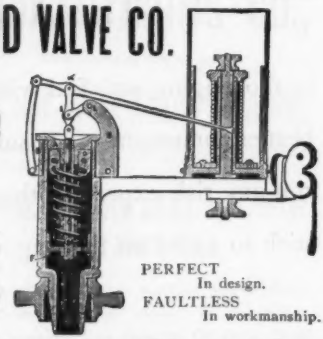

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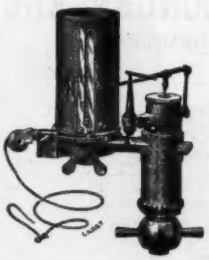

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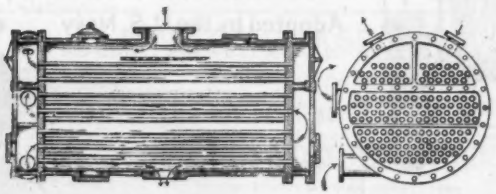

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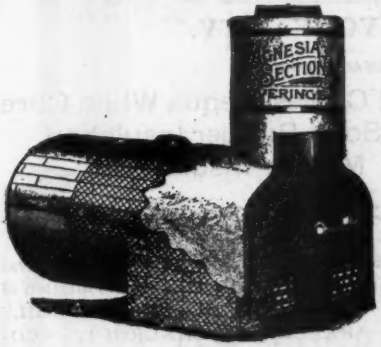

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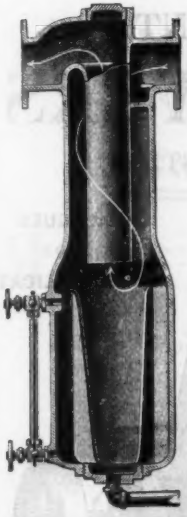

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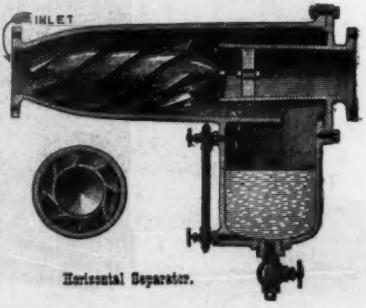

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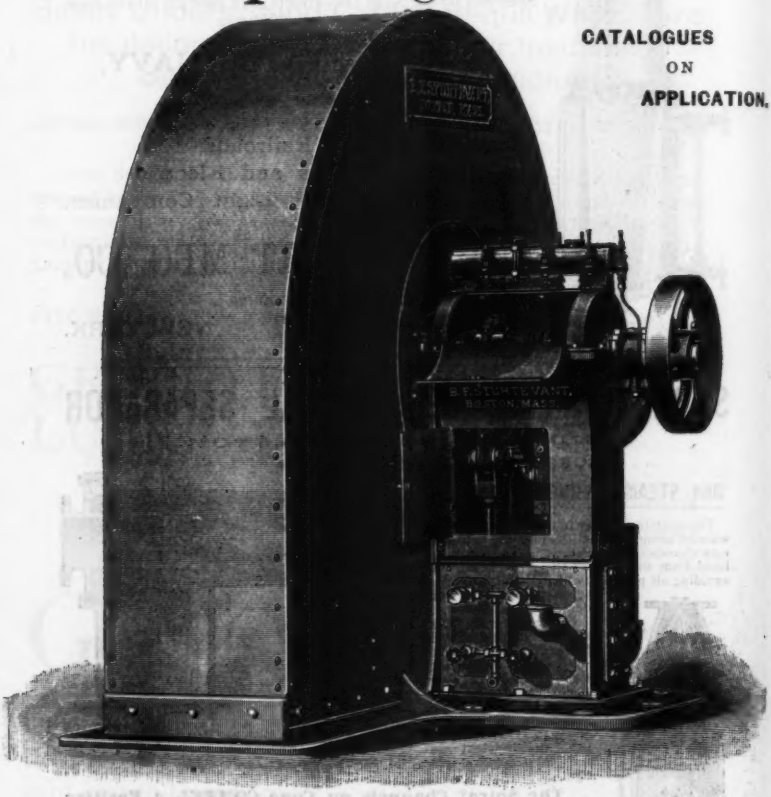

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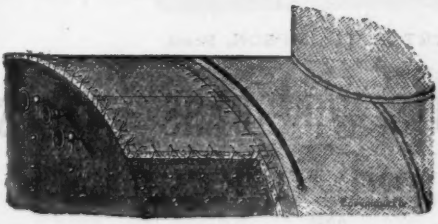

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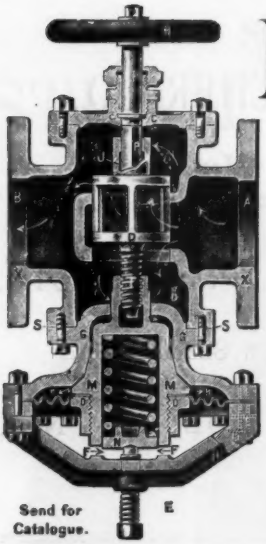

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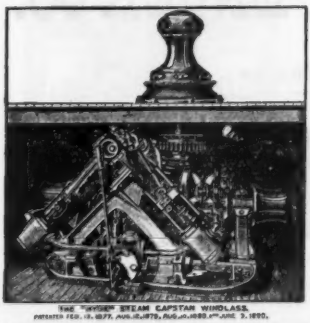

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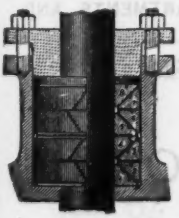

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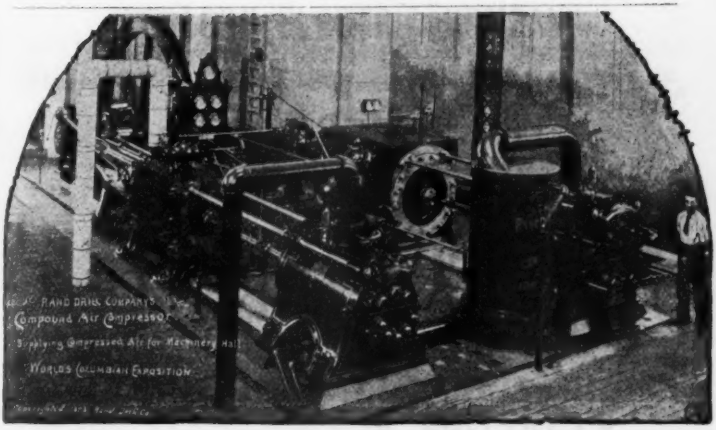

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Edited under the supervision of

COMMODORE GEORGE W. MELVILLE, Engineer-in-Chief, U. S. N.

These include more than forty papers by the leading naval architects and marine engineers of the world, together with the discussions of the papers by eminent professional men, the whole forming a book of about 1,200 pages, including over 200 illustrations, many of which are reproductions of working drawings of hulls and machinery.

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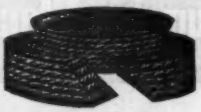

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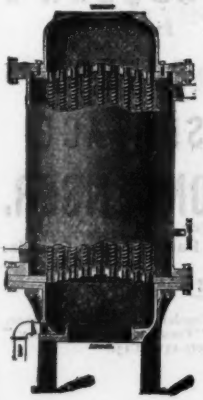

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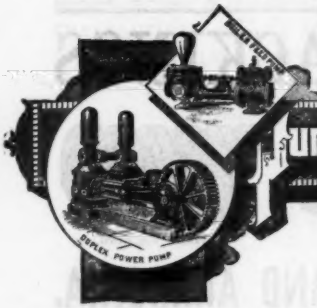

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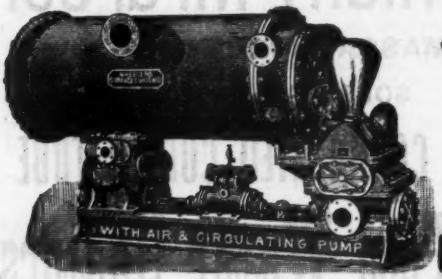

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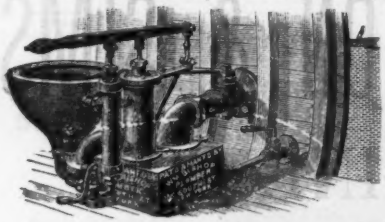

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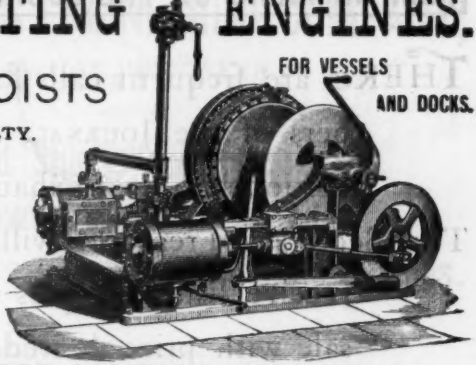

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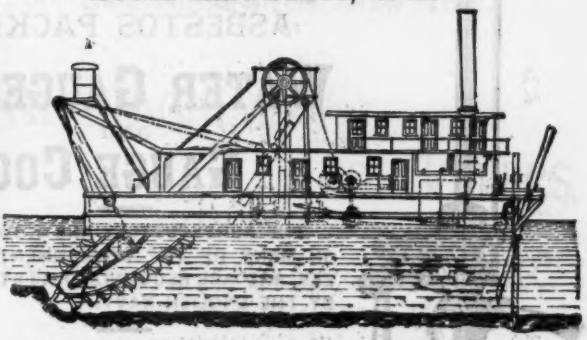

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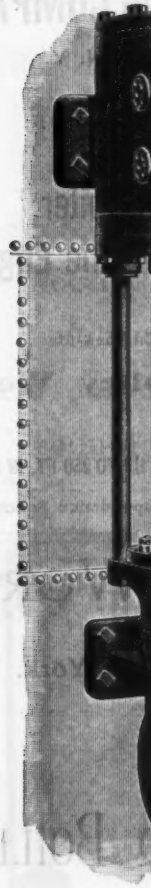

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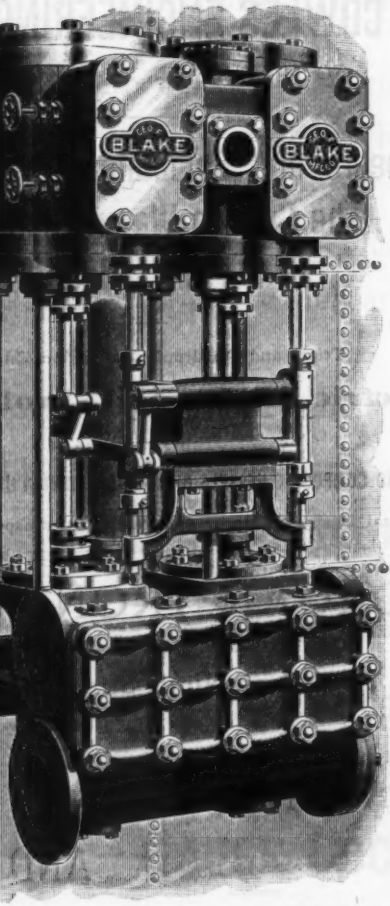

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VOL. V. NOVEMBER, 1898. No. 4.

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DIGEST OF PROFESSOR CECIL H. PEABODY'S EXPERIMENT WITH THE GEORGE F. BLAKE MANUFACTURING COMPANY'S PUMPING ENGINE SUPPLYING POTABLE WATER TO THE CITY OF NEWTON, MASS.

BY CHIEF ENGINEER ISHERWOOD, U. S. NAVY.

The experiment whose conditions and results are given in this paper was made by Professor Cecil H. Peabody, of the Massachusetts Institute of Technology, to ascertain whether the contract guarantees of a pumping engine designed and constructed by the George F. Blake Manufacturing Company for the city of Newton, Massachusetts, had been fulfilled.

The object of the experiment was not to make a scientific investigation of an interesting engineering subject, but to make simply a direct practical test, which should be decisive for the commercial purpose of ascertaining whether the guaranteed "duty," calculated according to a prescribed method, was obtained, all the necessary quantities involved being determined

with as much precision as the best skill, using the best instruments, could accomplish.

The experiment, however, embraced the taking of many more data than just those required for the commercial test, and as these additional data allow the determination of some facts of value in engineering, the writer has included in the present paper whatever supplementary information he could collect not found in Professor Peabody's report, which, indeed, gives the bare experimental quantities only.

The quantities experimentally ascertained were the weight of fuel consumed and the weight of refuse from it; the weight of feed water pumped into the boiler, and its temperature; the number of double strokes made by the pistons of the engine; the steam pressure in the boiler, and in the steam pipe just in advance of the throttle valve; the weight and temperature of the water of liquefaction drained from the live steam side of the reheater; the pressure of the water in the main just beyond the delivering valves of the main pumps; the vertical height between the level of the water in the pump well and the point at which the pressure in the main was taken; and the indicated pressure on the piston of each steam cylinder.

The coal, its refuse, and the feed water, were exactly weighed on tested scales. The water level in the boiler at the end of the experiment was made precisely the same and under the same pressure as at the beginning. This level did not vary sensibly during the experiment. The water drained from the reheater, due to the liquefaction of steam of supposed boiler pressure, was delivered into a barrel of cold water in order to prevent loss by evaporation under the atmospheric pressure. The barrel and its cold water being weighed before and after the reheater water was received into it, the difference gave the weight of that water. The temperature of the reheater water was taken by a thermometer in a cup 9 inches deep, filled with oil, and inserted into the water close to its escape from the reheater. The pressure in the reheater was not taken.

The pressures in the boiler, in the steam pipe adjacent the throttle valve and in the condenser, were taken by tested gauges.

The pressure of the atmosphere was taken by a mercurial barometer. The suction pressure, against which the plungers of the main pumps worked, was determined solely from the height of the column of water, not allowing in any way for the resistances of the foot valve, pump valves, or of the surface of the suction main. To determine this water column, a pipe from the forcing main was led to a closed chamber conveniently placed over the well. This chamber was partially filled with air, and was supplied with a water glass at the side and a pressure gauge at the top. A float in the well carried a graduated rod, which moved freely near the water glass on the above-mentioned closed chamber. The mean effective pressure under which the pump plungers worked was taken to be the pressure equivalent of the water column from the level of the water in the well to the level in the closed chamber plus the pressure shown by the gauge on the top of this chamber. No indicator diagrams were taken from the pump chamber between the receiving and delivering valves.

The water of liquefaction drained from all the steam jackets of both cylinders and the water of liquefaction drained from the reheater were trapped out and wasted, not being pumped back into the boiler. None of this water was weighed, nor was its temperature taken. The water of liquefaction from the steam pipe was, from the manner of supplying steam to the engine, delivered into the jacket of the small cylinder, and thence drained off with the normal water of liquefaction from that jacket. Of course, any water primed from the boiler would be delivered into the jacket of the small cylinder, and drained off in the same way without entering this cylinder.

The degree to which the pumps filled with water was not ascertained, and as they did not pump into a reservoir maintained at a known height of water, the statical pressure in the main cannot be compared with the dynamical pressure.

Each cylinder had an indicator at each end, as close to the cylinder as possible, and connected with it by a short, straight pipe of large diameter. To avoid any error from cord stretching, a brass rod was used, making the gear metallic, and it was per-

fectly accurate as to the reducing mechanism. Two assistants were employed to take the diagrams by signal simultaneously from both cylinders. The indicators were carefully tested, as were also all the thermometers and gauges employed. A set of diagrams (four in number) was taken every fifteen minutes, and the results given are the mean of all.

The diameters of the plungers of the pumps and of their piston rods were calipered. All other dimensions were furnished by the builders of the engine.

All the data were observed every fifteen minutes, and the mean taken for the calculations.

The speed of the engine was given by a counter worked by the engine.

The boiler was not built by the contractors for the engine, and they were not in any way responsible for its performance.

The pipe supplying the reheater with boiler steam was inadvertently attached to the bottom of the large horizontal steam drum of the boiler, and, consequently, delivered into the reheater the water of liquefaction due to the radiation of heat from the external surfaces of that drum, as well as all the similarly-caused water in the pipe itself, which pipe was greatly longer than necessary. Immediately after the experiment, this pipe was changed to take steam from the upper side of the main steam pipe as near the engine as practicable.

The engine was extremely well designed; the piping, valves, etc., were of large area; the materials and workmanship were excellent, and all the proportions adopted were such as to produce a maximum economy of the steam, and to give the purchaser a durable machine which can easily be made to develop one-half more power than was exerted during the experiment. The mechanical working was all that could be desired, noiseless, smooth and regular, without undue strains and without the least heating of the working parts from friction. The guarantees were all considerably more than fulfilled. The proportion of the total power developed by the steam (calculated down to the zero of pressure), utilized for commercial work, was carried to the maximum practicable. These facts, taken in connection with the

accuracy of the test, make the results especially valuable in an engineering point of view.

The following is a description of the engine, followed by the data and results of the experiment:

All the surfaces in contact with steam, from boiler to condenser, were thoroughly covered with non-heat-conducting material.

ENGINE.

The engine is a horizontal, jet condensing, receiver compound, with both cylinders steam jacketed on their sides and on their ends. Both cylinders are fitted with the well known Corliss valve system, each cylinder having at each end a steam valve and an exhaust valve worked separately by two independent eccentrics keyed upon the shaft. The steam valves of both cylinders cut off by lap, and there are no other cut offs. The axes of the two cylinders are in the same horizontal plane, parallel, and 10 feet apart. The steam valves are at the upper side of the cylinders, and the exhaust valves are at the lower side, one of each at each end of each cylinder.

The steam is brought from the boiler by a cast-iron pipe 63 feet in length, of which the first 27 feet are $9\frac{1}{2}$ inches in inside diameter, and the remaining 36 feet are $6\frac{1}{2}$ inches in inside diameter. The pipe has five right-angled bends. Its least cross area is 33.1831 square inches, or about 5 per centum more than the area of the steam port of the small cylinder.

The steam enters the top of the jacket surrounding the small cylinder, and then passes through the Corliss steam valves into the small cylinder until the cutting off is effected; consequently, the pressures in the jacket are nearly the same, *pari passu*, as in the cylinder up to the point of cutting off, the pressures in the jacket being only as much greater than in the cylinder as is required to move the steam from the one to the other. The jacket is thus made to act as a trap for any water that may be delivered by the steam pipe, whether owing to priming or to external refrigeration.

After the piston of the small cylinder completes its stroke, the steam is exhausted through Corliss valves into a cast-iron

cylindrical receiver which contains reheating tubes. The inside diameter of this receiver is 12 inches, and its length is 12½ feet. It is connected at one end with the small cylinder by a cast-iron pipe of 8¾ inches inside diameter, and 8½ feet length, having two nozzles for the two exhaust valves of the small cylinder; and it is connected at the other end with the large cylinder by a cast-iron pipe of 10¼ inches inside diameter, and 7½ feet length, making the total distance traversed by the steam in going from the small cylinder to the large one about 26 feet.

The exhaust steam from the small cylinder is delivered into the bottom of the jacket surrounding the large cylinder, from which jacket it passes through Corliss valves into the large cylinder until the cutting off is effected; consequently the pressures in the cylinder are nearly the same, *pari passu*, as in the jacket, up to the point of cutting off; the jacket pressures being only sufficiently greater than the cylinder pressures to force the steam from the one to the other.

The steam space between the exhaust valves of the small cylinder and the steam valves of the large cylinder, including the space in the jacket surrounding the large cylinder, is about 24 cubic feet, or, say, three times the capacity of the small cylinder, or, say, three-fourths the capacity of the large cylinder, which space may be considered as constituting the receiver.

The reheater placed in this space consists of fifty-six copper tubes ¾ of an inch in outside diameter, and 10 feet 11½ inches long between tube plates, the copper being one sixteenth of an inch thick. Through these tubes the whole of the steam exhausted from the small cylinder passes on its way to the large cylinder. The tubes are surrounded by steam taken direct from the boiler, and the water resulting from its liquefaction and from the liquefaction due to radiation of heat from the external surfaces of the reheater, is pumped back into the boiler by a special pump. The tubes are expanded into one tube plate, and are provided at the other tube plate with packed stuffing boxes and screw followers, in order to allow them to contract and expand with changes of temperature. The aggregate inside surface of the tubes is 120.5 square feet. The reheater forms a separate

compartment in the conduit conveying the steam from the small to the large cylinder.

The exhaust steam from the large cylinder to the condenser passes through a cylindrical conduit of cast iron 23 feet long, of which 19½ feet are occupied as a heater for the feed water. The inner diameter of the heater portion of the pipe is 18¼ inches, and of the remaining portion 13 inches. The exhaust pipe adjacent to the large cylinder has two nozzles, one for each exhaust valve.

The jet condenser is a cast-iron cylinder 12 inches in inside diameter and 13 feet in length, placed with its axis horizontal. The injection pipe is 6 inches in inside diameter. It enters the condenser sufficiently to expose two slots, each ⅝ths of an inch in width and 22½ inches in length, for the delivery of the injection water into the condenser. These slots are in the upper half of the pipe, are parallel to the axis of the pipe, and are 90 degrees apart—45 degrees on each side of the vertical. The axes of the condenser and of the pipe are in the same horizontal line, and the end of the pipe is closed.

The condenser is connected to the air pump by a pipe 10 inches in inside diameter and 13 feet in length. The center of the condenser is 7 feet below the center of the cylinder, and the center of the stroke of the air pump piston is 2½ feet below the center of the condenser.

The air pump is vertical, single acting, and lifting, with valves in its piston. It is worked from a bell-crank movement given by the engine.

The feed-water heater consists of thirty-six coils of 2 inches inside diameter copper pipe, with straight extensions, and having a total length of 142 feet measured on its axis. It exposes to the exhaust steam from the large cylinder 74.35 square feet of inside surface. These coils form a portion of the feed pipe, and all the feed water, excepting what water of liquefaction passes direct to the boiler from the reheater, passes through them on its way to the boiler. The waters of steam liquefaction in the jackets are not pumped back to the boiler when the engine is in normal use, though it may easily be done when re-

quired. The jacket surrounding each cylinder is cast in the same piece with it.

The fly wheel is placed midway between the two cylinders, with the axis of its shaft 2 feet 5 inches below the horizontal plane passing through the axes of the two cylinders. Two horizontal parallel links from the crosshead of each cylinder vibrate a vertical lever, from which a connecting rod passes to the crank of the fly-wheel shaft, and gives it rotary motion. This shaft has a crank at each end one foot long between centers. The diameter of the shaft is 9½ inches. The cranks are at right angles to each other.

The air pump is worked from a horizontal arm keyed on one end of the shaft of the vibrating lever of the large cylinder. Of course, there is a duplicate vibrating lever for the small cylinder, but it has no arm for working a pump.

The main water pumps are two in number, one for each cylinder. They are duplicates, horizontal and double acting, with their axes in the same horizontal plane with the axes of the cylinders. The piston of each pump is worked direct by a prolongation of the piston rod of the cylinder working it. Both pumps draw from one cast-iron suction pipe of 24 inches inside diameter by means of branch pipes 20 inches in inside diameter. The large suction pipe is surmounted by a cast-iron air vessel of 24 inches inside diameter and 10 feet 9 inches height.

At each end of each pump are two sets of valves, one for receiving, the other for delivering water. Each set rests upon a horizontal seat, and consists of fifty-five circular valves of vulcanized caoutchouc 3½ inches in diameter and nine-sixteenths of an inch in thickness; diameter of the opening, 3 inches. Both ends of each pump deliver into one chamber placed immediately above the pump, there being one such chamber for each pump. From the center of the top of each of these chambers the water passes into the main by cast-iron branch pipes of 20 inches inside diameter. Each branch pipe is surmounted by a cast-iron air vessel of 30 inches inside diameter and 5½ feet height. The main is a cast-iron pipe of 24 inches inside diameter.

Each cylinder is tied to the casting of its opposite pump by

two wrought-iron bars of rectangular cross section, the axes of which are in the same horizontal plane as the axis of the piston rod. These bars serve also as guides for the main crosshead.

The entire engine—cylinders, pump castings, etc.—is mounted upon and bolted to massive foundations of brick masonry.

The following are the dimensions and proportions of the principal parts:

Number of cylinders	2.
Diameter of the small cylinder, inches	21.
Diameter of the piston rod of the small cylinder, inches	4.
Net area of the piston of the small cylinder, square inches	340.077403
Stroke of the piston of the small cylinder, inches	40.
Space displacement of the piston of the small cylinder per stroke, cubic feet	7.872170
Area of the steam port of the small cylinder (21 by 1½ inches), square inches	31.5
Area of the exhaust port of the small cylinder (21 by 2½ inches), square inches	52.5
Space in steam passage and clearance at one end of small cylinder, cubic foot	0.326456
Fraction which the space in the steam passage and clearance at one end of the small cylinder is of the space displacement of the piston of that cylinder per stroke	0.041470
Diameter of the large cylinder, inches	42.
Diameter of the piston rod of the large cylinder, inches	4.
Net area of the piston of the large cylinder, square inches	1,379.159169
Stroke of the piston of the large cylinder, inches	40.
Space displacement of the piston of the large cylinder per stroke, cubic feet	31.924981
Area of the steam port of the large cylinder (40½ by 1⅞ inches), square inches	75.937500
Area of the exhaust port of the large cylinder (40½ by 3¼ inches), square inches	131.625000
Space in steam passage and clearance at one end of large cylinder, cubic feet	1.262532
Fraction which the space in the steam passage and clearance at one end of the large cylinder is of the space displacement of the piston of that cylinder per stroke	0.039547
Ratio of the space displacement of the piston of the large cylinder per stroke plus the space in the steam passage and clearance at one end of that cylinder, to the space displacement of the piston of the small cylinder per stroke plus the space in the steam passage and clearance at one end of that cylinder	4.047936

Ratio of the net area of the piston of the large cylinder to the net area of the piston of the small cylinder, the latter being unity	4.055427
Number of air pumps (single acting and vertical)	1.
Diameter of air pump, inches	26.
Stroke of air pump piston, inches	12.
Space displacement of air pump piston per stroke, cubic feet	3.687017
Diameter of main feed pump (one and single acting), inches	4.5
Stroke of main feed-pump piston, inches	6.
Space displacement of main feed-pump piston per stroke, cubic foot	0.055223
Outside diameter of reheater (cast iron and horizontal), inches	13.25
Inside diameter of reheater, inches	11.50
Length of reheater between flanges of caps, feet	12.33
Number of copper tubes in reheater	56.
Outside diameter of reheater tubes, inch	0.750
Inside diameter of reheater tubes, inch	0.625
Length of reheater tubes between tube plates, feet	10.958333
Aggregate outside surface of reheater tubes, square feet	120.493168
Aggregate inside surface of reheater tubes, square feet	100.410973
Distance between axes of reheater tubes, vertical and horizontal, inches	1.25
Aggregate cross area of reheater tubes, square inches	17.180240
Diameter of reheater nozzles for steam from and into cylinders, inches.	10.
Diameter of pipe supplying boiler steam to reheater jacket, inches	1.5
Number of coils of copper feed pipe in feed-water heater	36.
Inside diameter of the pipe composing the coils, inches	2.
Diameter of the coils from center to center of pipe, inches	14.
Length of the coil and straight parts of the pipe, feet	142.
Surface of the coil measured on its inside, square feet	74.351200
Diameter of the pump (single acting) for delivering the water of liquefaction from the reheater into the boiler, inches	2.
Stroke of the same, inches	6.
Number of main pumps, double acting and horizontal	2.
Diameter of main pumps, inches	13.5
Diameter of piston rods of main pumps, inches	4.
Net area of each main pump piston, square inches	136.855629
Stroke of the pistons of the main pumps, inches	40.
Space displacement of each main pump piston per stroke, cubic feet	3.167954
Ratio of the net area of the piston of the large cylinder to the aggregate net areas of the pistons of the two main pumps	5.038737
Number of receiving valves, and also of duplicate delivering valves, at each end of each main pump	55.
Aggregate area through the delivering valves, and also through the receiving valves, at each end of each main pump, square inches	260.7
Ratio of the area through the valves of the main pumps to the net area of the pistons of these pumps	1.904927

EXPLANATION OF THE FOLLOWING TABLE CONTAINING THE DATA AND RESULTS OF THE EXPERIMENT.

In the following table the quantities have been grouped, and the lines containing them numbered, for facility of reference. The description on each line is so complete that but little additional explanation is required.

Total quantities.—The duration of the experiment (line 1) was exact by a correct time piece. And the number of double strokes made by the pistons of the steam cylinders and of the pumps during that time (line 2) was taken by an accurate counter worked by the engine.

The total number of pounds of feed water consumed (line 3) was accurately weighed into a tank, whence it was forced into the boiler by the feed pump of the engine, the water level in the boiler at the beginning and end of the experiment being at the same mark on a glass water gauge and under the same steam pressure. This quantity of water is the whole, without deduction of any kind, pumped into the boiler during the experiment, and it includes the quantity on line 4, as well as the water of liquefaction from all the jackets of both cylinders, which latter water was wasted without being measured, not being pumped back into the boiler, nor was its temperature ascertained. The quantity on line 4 was weighed, but not pumped back into the boiler.

The number of pounds of water of steam liquefaction drawn from the reheater (line 4) is included in the quantity on line 3. The quantity on line 4, owing to an oversight in the arrangement of the pipe supplying steam to the reheater, is greatly above the normal. The steam for the reheater was taken from the bottom of the horizontal steam drum of the boiler by means of a very long pipe, which consequently delivered into the reheater not only steam, but any water present in the drum from any cause, besides the water of liquefaction due to external radiation of heat from the surface of the pipe.

The total number of foot pounds of work done by the steam pistons during the experiment (line 5) includes the work of overcoming the back pressures against these pistons, and was calculated as follows:

Total horse power (line 76) × 33,000 × 10 × 60 = line 5.

The total number of foot pounds of work done by the pistons of the main pumps (line 6) is the product of the pressure in pounds per square inch (line 39), by the number of square inches in the aggregate area of the pistons, by the speed of the pistons in feet per minute (251.3), and by the number of minutes (600) that the experiment continued. The pressure against which the pistons of the pump worked (line 37) is exclusive of the resistances of the pump valves, and of the various surfaces and sinuosities between the water level in the pump well and the chamber immediately beyond the delivery valves. Repeated trials showed no difference between this pressure and the pressure in the chamber between the receiving and delivering valves against which the pump pistons acted. Of course, the pressure in the space between the valves must have been greater than in the chamber beyond the delivering valves, but the difference was not sensible with the instruments used, owing to the large diameter of the suction pipe, to the very great area of valve opening relatively to area of pump piston—namely, nearly two of the former to one of the latter—and to the low lineal speed of the pump piston (251.3 feet per minute).

Line 7 shows the number of Fahrenheit units of heat imparted to the feed water in the boiler. The units of heat in one pound of the feed water when entering the boiler were 116.133280 above what were in it at the Fahrenheit zero, and the units of heat in one pound weight of steam of the boiler pressure above the same zero were 1,221.125418, consequently, the difference (1,104.992138) multiplied by the number of pounds of feed water on line 3 will give the quantity on line 7.

Line 8 shows the fraction which the work done by the pump pistons is of the work done by the steam pistons. This fraction is the quotient of the division of the quantity on line 6 by the quantity on line 5. The fraction on line 8 represents, relatively to unity, the efficiency of the mechanism. The work done by the steam includes overcoming the back pressure, exclusive of any cushioned pressure, against the steam pistons, which is as much work done as the water pumped is; now the back pres-

sure depends, other things equal, on the efficiency of the valve gear, on the dimensions of the valve openings relatively to capacity of cylinder and speed of its piston, on the adjustment of the valves, on the length and sinuosity of the steam passages, etc., etc. The more judicious the design of the valves and their gear, etc., the less, with equally tight joints and the same temperature in the condenser, will be the work done on the back pressure. Habitually, the fraction expressing the efficiency of the mechanism is obtained by dividing the horses power exerted at the pump pistons by the indicated horses power developed by the steam pistons, and the practice has arisen from the erroneous idea that the indicated horse power is the entire power of the engine, while it is, in fact, only the portion which remains of that power after deducting the power required to overcome the back pressure against the steam pistons. The difference between the fraction thus obtained and unity represents the fraction of the indicated horses power expended in working the engine *per se*, or unloaded. But the friction of the unloaded engine is not the only loss of useful effect experienced by an engine; any increase of back pressure over the condenser pressure due to bad proportion of valve opening or bad setting of the valves, is equally a loss of useful effect and must be included against the engine. The increase of back pressure, with equal temperature of condenser, due to air leakage through vacuum joints, is a consequence of careless workmanship and must be included against the commercial efficiency of the engine. The fraction representing the useful or commercially valuable work obtained, relatively to the entire power developed by the engine, is only of commercial importance, because, really none of the total power can be lost, as it produces its full effect on the various resistances opposed to it.

The quantity on line 9 shows the number of foot pounds of work done by the steam pistons per Fahrenheit unit of heat expended. This quantity is the quotient of the quantity on line 5 divided by the quantity on line 7. Such quotients for different engines express their different economies as regards the total work done in them by the steam, and can, consequently, be used

to denote the relative economic efficiencies of these engines in this respect; but their principal value consists in enabling a comparison to be easily made between the work that can theoretically be done by one unit of heat and the mass work that actually was done by the engines when operating with a given regimen of steam. A comparison with a perfect engine is thus obtained. A perfect engine is one that transmutes the entire heat in the steam, or the entire *vis viva* of its molecules, into mass work. It not only loses no heat by its mechanism and the properties of its material, but the steam it uses is supposed to be without molecular cohesion, the entire heat being transmuted into mass work, the steam in that case acting merely as a perfect heat carrier transferring all the *vis viva* it received and doing no internal work upon itself. Accepting one unit of heat as equivalent to 789.25 foot pounds of work, the engine, which is the subject of the present investigation, transmuted into mass work (131.6674 ÷ 789.25 =) 0.1668 of the work in the steam.

In the same manner, making the comparison for the mass work done at the pump pistons—that is, for the commercial work done by the engine—113.8163 foot pounds of such work were done by the expenditure of one unit of heat (line 10), or, there was realized by the engine as commercial work (113.8163 ÷ 789.25 =) 0.1442 of the total heat in the steam.

ENGINE.

The pressures given under this head were all taken by carefully corrected gauges, and need no explanation.

The points in the stroke of the pistons of the steam cylinders at which the steam was cut off, released, and cushioned, were obtained from the indicator diagrams. These diagrams were taken every fifteen minutes by tested indicators from each end of each cylinder, as was also a full set of corresponding data. The almost absolute uniformity of the work made the diagrams and data substantially repetitions.

Line 24 shows the number of times the steam was expanded in the small cylinder. This quantity represents the relative spaces occupied by it in the small cylinder at the closing of the

cut-off valve and at the end of the stroke of the piston. These spaces include the clearance at one end of the cylinder, but they cannot represent the real expansion of the steam, because of its constant liquefactions, and of the revaporization of such liquefactions, throughout the stroke of the piston. Nor, for the same reason, can any nearer approach to the truth be made by assuming the steam pressures at the point of cutting off, and at the end of the stroke of the piston of the small cylinder, to represent inversely the expansions undergone by the steam.

Line 25 gives the number of times the steam was expanded in the engine. This quantity, in fact, represents only the ratio of the space in the small cylinder occupied by the steam before the closing of the cut-off valve, including the waste space at one end of that cylinder, and in the large cylinder between the faces of the valves and the end of the stroke of the piston. Beside the causes already shown as preventing a knowledge of the real expansion undergone by the steam in a cylinder, there is, additionally, with the present engine, the fact that the weight of steam entering the large cylinder is less than the weight of steam leaving the small cylinder, by the unknown weight liquefied in the jacket of the large cylinder. The steam in the engine in question was expanded more than is shown on line 25.

The difference between the pressure of the steam in the boiler (line 15) and the pressure of the same in the steam pipe just in front of the throttle valve and near the small cylinder (line 17) is (137.46 — 134.70 =) 2.76 pounds per square inch. The least cross area of this pipe was 33.1831 square inches, and the area of the small cylinder was 340.077403 square inches, these areas comparing nearly as 1 to 10¼. The length of the pipe was 63 feet, and it was thoroughly clad with non-heat-conducting material. The steam was cut off in the small cylinder at one-fifth of the stroke of its piston, the pipe having the time required to make the remaining four-fifths of the stroke to regain any loss of pressure below the boiler pressure; nevertheless, under all these favorable conditions, there was a loss of 2.76 pounds per square inch of pressure between the two ends of the pipe. This difference represents the head required to supply the steam to

the small cylinder, the steam expanding continuously from one end of the pipe to the other. In this particular case the loss of pressure was a little over 2 per centum.

The pressure in the small cylinder at the point of cutting off the steam is (line 41) 128.862 pounds per square inch above zero, or (137.460 — 128.862 =) 8.598 pounds per square inch less than the boiler pressure, a loss of 6¼ per centum between the boiler and the point of cutting off the steam, 4¼ per centum being lost by the resistance of the valves and steam passages. These losses of pressure would be increased by any increase of the speed of the steam pistons, the boiler pressure remaining the same.

The pressure in the condenser (line 19) was 1.506 pounds per square inch above zero. The back pressure in the large cylinder, exclusive of cushioning (line 53) was 2.800 pounds per square inch above zero, showing that the piston of the large cylinder had to compress this steam (2.800 — 1.506 =) 1.294 pounds per square inch to give it the necessary "head" to flow by its own expansion into the condenser against the resistances of the valves, steam passages, etc.

TEMPERATURES.

The temperatures on lines 27 and 28, and on line 36, are those which correspond to the steam pressures on lines 15 and 17 and on line 52; all the other temperatures were taken by tested mercurial thermometers.

The temperature of the feed water, when entering the coil for heating it by the exhaust steam from the large cylinder, was 59 degrees Fahrenheit (line 29) and when leaving this coil, 122 degrees (line 30,) the water having thus received 63.1476 units of heat (line 31).

The weight of feed water passing per hour through this coil was 3,822.95 pounds. The inside heating surface in the coil was 74.3512 square feet; consequently, each square foot of this surface passed per hour (63.1476 ÷ 74.3512 =) 0.849315 Fahrenheit units of heat into 3,822.95 pounds of water, or the heat passed per hour per square foot of the coil was (3,822.95 ×

0.849315 =) 3,246.8888 Fahrenheit units, which, of course, was abstracted from the exhaust steam.

The temperature, 122 degrees, of the feed water when leaving the coil (line 30) was sensibly the same whether, on entering the coil, it had the temperature on line 29 (59 degrees) or the temperature of the hot well on line 34 (98 degrees), or a much lower temperature than 59 degrees. The quantity of heat abstracted by the water from the exhaust steam was small relatively to the quantity of heat in that steam, and as the temperature imparted to the water could not exceed the temperature of the exhaust steam, the temperature of the water on leaving the coil would remain constant, let its temperature on entering the coil be what it might, as long as the entering feed water did not exceed a certain quantity. Of course, if the quantity of feed water be made sufficiently great, its final temperature will be influenced by its initial temperature, the latter being less as the former is less. With the facts as they were, the coil would have delivered the feed water at the constant temperature, 122 degrees, had it entered the coil at 32 degrees, consequently, the heat transmissible per hour per square foot of the coil surface would be proportionally more than the 3,246.8888 units given at the close of the immediately preceding paragraph. The commercial gain due to the use of the coil, is measured by the additional temperature it imparted to the portion of the feed water that would otherwise have been taken direct from the hot well; that is to say, the coil raised the temperature of this portion of the feed water from 98 to 122 degrees, an increase of 24 degrees, and well worth having, as it effected an economy of fuel of about 2 per centum. As this economy is due to the temperature of the exhaust steam when leaving the large cylinder, the higher that temperature the greater the economy from this source; but that temperature can only be increased by increasing the pressure at the end of the stroke of the piston of the large cylinder, which involves using the steam with less expansion. The gain thus obtained from the increased temperature of the feed water may easily equal, and possibly exceed, the loss suffered by using the steam with less expansion, under certain

conditions, as, for example, when the measure of expansion is already excessive. In this case the gain will be a smaller engine to do the same work with equal economy, against which must be placed the cost of the coil.

For the rather small measures of expansion habitually used with marine engines, giving a comparatively high pressure at the end of the stroke of the piston of the large cylinder, the economic gain obtainable by heating the feed water by the exhaust steam, may be sufficiently large to be of considerable practical importance. This system was proposed to the Navy Department at least 40 years ago, but has never been adopted or even experimented with, and it should no longer be neglected. The feed water can undoubtedly be heated to nearly the temperature of the exhaust steam by the simple insertion of a small surface condenser in the exhaust pipe between the large cylinder and the main condenser, the nearer the cylinder the better, the feed water taken from the hot well acting as the injection water. With this system the water in the hot well can be carried as cold as is found to give additional vacuum in the main condenser, and without lessening the temperature of the feed water when entering the boiler. The gain due to higher temperature of feed water is more than is measured by the difference in degrees, because the economic vaporization by the fuel in the boiler is correspondingly increased by increase of temperature of the feed water; consequently, to develop the same power for equal times, other things remaining the same, less weight of coal will have to be carried in the bunkers, and the work of firing it will be easier for the same number of men; the cost of the fuel will also be less; add to all these some gain due to the better vacuum in the condenser caused by the colder hot well, and the aggregate will be found to be an important quantity.

The pressure of the exhaust steam between the large cylinder and the main condenser continuously decreases with correspondingly decreasing temperatures, so that the location of the feed-water heater becomes of importance. It should obviously be placed as near the cylinder as possible, as the exhaust pressures

decrease with great rapidity at first. In the case of the engine in question, the temperature 122 degrees of the feed water when leaving the coil was probably about the mean temperature of the exhaust steam surrounding the coil; this temperature corresponds to a pressure of 1.78 pounds per square inch above zero. The pressure in the large cylinder at the end of the stroke of its piston was 7.60 pounds per square inch above zero, the temperature due to which is 181.7 degrees. The pressure of the mingled steam and air in the condenser was 1.50 pounds per square inch above zero, but the steam pressure alone was, of course, much less. The temperature of the condenser was probably about 102 degrees, the steam pressure corresponding to which is 1 pound per square inch above zero, leaving 0.50 pound for the pressure of the air. Supposing the injection water, averaging, say, 70 degrees, to be supplied in sufficient quantity to reduce the temperature of the condenser to, say, 80 degrees, the pressure corresponding to which is 0.50 pound per square inch above zero, then the gain would be $(1.00 - 0.50 =)$ 0.50 pound per square inch of pressure upon the piston of the large cylinder. The net pressure on that piston was 12.42 pounds per square inch (line 57), of which 0.50 pound is 4 per centum, equal to a gain of $(130.4 \times 0.04 =)$ 5.216 net horses power developed in that cylinder. The aggregate net horses power developed by the engine (line 75) was 242.827, of which 5.216 are 2.15 per centum; that is to say, the commercial value of the fuel would be increased this per centum by the changes above given as an illustration of the possible economic gain.

With the pressure habitually found at the end of the stroke of the piston of the large cylinder, a considerable amount of heat is wasted for want of a feed-water heater placed in the exhaust steam very close to the cylinder, as, for example, supposing that pressure to be equal to 12 pounds per square inch above zero, and that it falls to 4 pounds in the heater with the corresponding temperature of 153 degrees, the temperature of the hot well being 100 degrees, a gain of about 5 per centum of the fuel would be obtained, not including the other accompanying gains above pointed out, which possibly might aggregate 5 per centum more, making a total of 10 per centum.

As the temperature of the feed water when entering the boiler was only 116 degrees (line 32), there had been lost by external radiation from a feed pipe of about 63 feet length (122 — 116 =) 6 degrees of temperature, equivalent to over one-half of one per centum of the fuel, and strongly illustrating the necessity of thoroughly covering such pipes with a non-heat-conducting substance.

The temperature of the water of liquefaction drawn from the reheater, line 33, was 322.7 degrees Fahrenheit. The temperature of the steam in the boiler from which the reheater was supplied was 351.42 degrees; the difference between the two is 28.72 degrees. As the pressure of the steam in the reheater was not taken, there cannot be known whether that pressure was equal to the boiler pressure or whether it was less, nor how much of the above difference of temperature was due to possible difference of pressure. The pipe supplying the reheater was a long one, and only 1.5 inches in diameter; it carried a great deal of water as well as steam. A large portion of the difference of temperature was unquestionably due to the fact that the tube surface in the reheater on which the steam was liquefied was necessarily below the temperature of that steam. If the entire difference of temperature could be so accounted for, and probably it can, the temperature 322.7 degrees will be that of the tube surface.

If the weight of water drawn from the reheater (357.72 pounds per hour, line 4), had all been the result of steam liquefaction by the tubes of the reheater, and if the pressure of the steam in the reheater was known as well as the temperature of the water of liquefaction drawn from it, a calculation could be made of the number of units of heat transferred per hour from the boiler steam in the reheater to the exhaust of mingled steam and water in the receiver from the small cylinder. In Mr. Dean's 24 hours long experiment (page 471 of the May, 1893, number of this JOURNAL), 210.578 pounds of water were drawn per hour from the reheater, the pipe supplying it with steam having been so changed as to take the steam from the top of the steam pipe just in advance of the throttle valve. Accepting all the figures as accurate, the supply pipe during the present experiment must

have delivered into the reheater at least (357.720 — 210.578 =) 147.142 pounds of water per hour along with the steam. This water may be assumed as having the boiler temperature when entering the reheater, and, therefore answering the purpose of communicating heat to the tubes of the reheater, losing thereby the above 28.72 degrees of temperature. The reheater water, line 4, was not pumped into the boiler during the experiment, but during the regular working of the engine it is. This water was composed of water of liquefaction from the steam drum of the boiler; of water of liquefaction due to heat radiated from the external surfaces of the supply pipe; of water of liquefaction due to heat radiated from the external surfaces of the reheater, and to the water of liquefaction due to the transference of heat from the live steam in the reheater to the exhaust steam from the small cylinder in the reheater. It is impossible to ascertain the quantity of water of liquefaction, due to the radiation of heat, from the external surfaces of the reheater, but neglecting it, and supposing the boiler pressure to have been present in the reheater, and that 210.578 pounds of steam of that pressure had been liquefied per hour in the reheater, and that the temperature of the water of liquefaction had been reduced from the boiler temperature 351.42 degrees to the reheater temperature 322.7 degrees, and that the temperature of 147.142 pounds of water carried from the boiler and supply pipe into the reheater, had been reduced from 351.42 to 322.7 degrees, then the number of units of heat imparted per hour to the mingled steam and water in the receiver between the two cylinders, would be as follows:

Latent heat of 210.578 pounds weight of steam at boiler pressure, units...	182,265.00
Sensible heat taken from 210.578 pounds of water of steam liquefaction, units	6,317.34
Sensible heat taken from 147.142 pounds of water brought from the boiler and supply pipe into the reheater, units	4 414.26
Total, units	192,996.60

The above quantity of heat is equal to 4.57 per centum of the heat imparted in the boiler to the feed water.

The following question here arises, namely: Could any economic gain be made by using in the reheater the above per centage of the heat imparted in the boiler to the feed water rather than by using it in the engine? That is to say, supposing 4.57 per centum of the steam evaporated in the boiler to have been applied to the direct production of power by admitting it to the small cylinder, would the result economically have been greater than, equal to, or less than the result obtained by employing its latent heat in the reheater to act there upon the steam exhausted from the small cylinder previous to admission into the large cylinder? The mere statement of this question carries its own answer with it.

A reheater placed in the receiver of a compound engine can produce two effects only—it can superheat the exhaust steam from the small cylinder on its passage to the large cylinder, and it can boil off any water of surface liquefaction present in the receiver. To what cause can such water be due? None can come from the small cylinder, because every molecule of water of surface liquefaction in it is boiled off by the contained heat of the metal of that cylinder during the expansion portion of the stroke of its piston, and during the exhaust stroke, and by the contained heat of the water itself. The receiver receives only steam from the small cylinder, mingled intimately, of course, with the water of molecular liquefaction, due to the development of power by the expanding steam in the small cylinder, but this water, molecularly mixed with the steam, does not come in contact with the tubes of the reheater; only the mass water of surface liquefaction does that, the water of molecular liquefaction remaining suspended in the steam. The water that comes in contact with the tubes of the reheater is the mass water of surface liquefaction due to the radiation of heat from the external surfaces of the receiver, including in that term all the surfaces from the exhaust port of the small cylinder to the end of the reheater, but not those from the end of the reheater to the steam port of the large cylinder (a reheater should be placed as close to the large cylinder as possible), and if that water be drawn off as fast

as formed, and pumped back into the boiler, there will be none for the reheater to act on.

If the water, instead of being drawn off, is allowed to remain in the receiver, it will be vaporized there by the reheater with steam taken from the boiler and at the expense of the heat of that steam. The reheater is, in fact, as regards the vaporization of this water, an adjunct to, or extension of, the boiler; but there is this great economic difference between vaporizing the water in the reheater and in the boiler, that when the vaporization is done in the latter by the expenditure of a given quantity of heat, the resulting steam is used throughout the entire engine, small cylinder as well as large, and when it is done in the reheater the steam is used in the large cylinder only, producing, consequently, much less power. Thus, as far as regards the vaporization of the mass water in the receiver, the reheater is greatly less economical than the mere pumping back of this water into the boiler. In general, the power effect produced in the superheating of steam by the direct expenditure of heat, as, for example, by means of steam taken direct from the boiler instead of by waste heat taken from the chimney of the boiler, is no more than would be obtained from saturated steam evaporated in the boiler by the same expenditure of heat, and when such superheating is done in the receiver of a compound engine, a less economic effect is obtained, because the saturated steam evaporated in the boiler works throughout the engine, while, in the case of a reheater, the superheated steam works in only the large cylinder. If the large cylinder be not steam jacketed, superheating the steam in the reheater will be beneficial economically in the same way that steam jacketing is, by the prevention of surface liquefaction in that cylinder, and in this manner some gain will be obtained; but with an efficiently steam-jacketed large cylinder, the use of a reheater must produce some economic loss; that is to say, if the steam liquefied in the reheater had been worked through the engine—small cylinder and large—it would have produced a greater economic effect.

The interior surface of the tubes of the reheater contained 100.410973 square feet, which, under the conditions, transmitted

per hour per square foot of surface 192.2 Fahrenheit units of heat. The steam temperatures upon the opposite sides of the tube surface may be taken at 351 and 244 degrees, difference for superheating 107 degrees Fahrenheit.

Supposing the water of liquefaction due to the external radiation of heat from the surfaces of the receiver other than those of the reheater, be trapped out, as it always can be and should be under any circumstances, then the function of the reheater is solely to superheat at the expense of heat taken directly from the boiler, the exhaust steam passing through the reheater from the small to the large cylinder, and the simple question is What is the comparative economic effect of the weight of steam delivered to the reheater, whether it be there used in superheating the steam entering the large cylinder alone, or whether it be directly used as saturated steam in the production of power in both cylinders of the engine? Obviously, the most satisfactory answer to the question will be given by experiment, the result of which is shown in the table on the opposite page.

The quantities on the last line of the above table express directly the relative economic efficiencies of the three experiments. The equality of the results with and without the reheater in use is evident at a glance, the mean economic result of the two experiments with the reheater in use $\left(\frac{14.7351 + 15.2567}{2} = 14.9959\right)$ being almost exactly equal to the result with the reheater not in use (15.0005).

The comparison should have been made for the total aggregate horses power developed by the engine in the three experiments, taking the steam piston pressures down to the zero line, instead of for the pressures upon the pistons of the pumps, but probably the latter were sensibly in the ratio of the former, though not necessarily so. Exactness is scarcely possible with experiments made on so large a scale for so short a time as two hours. Where the difference sought is but trifling, it can easily be masked by the slight error in the level of the water in the boiler, due to variations of pressure not known to and beyond the control of the observer. The discrepancies in the last two columns of the table are no greater than might be

EXPERIMENTS MADE JUNE 9, 1892, TO ASCERTAIN THE ECONOMIC VALUE OF THE REHEATER.

	Reheater not in use.	Reheater in use.	
Duration of experiment, in hours	2.	2.	2.
Total number of double strokes made by the pistons	4,622.	4,584.	4,616.
Number of double strokes made per minute by the pistons	38.5167	38.2000	38.4667
Total number of pounds of feed water pumped into boiler	7,586.	7,272.	7,304.
Total number of pounds of water of liquefaction drawn from the reheater, included in the feed water	.....	440.	119.
Atmospheric pressure in pounds per square inch	14.6	14.6	14.6
Steam pressure at the throttle valve, in pounds, per square inch above atmosphere	116.0	119.25	119.0
Steam pressure at the throttle valve, in pounds, per square inch above zero	130.6	133.85	133.6
Pressure on the pistons of the pumps, in pounds, per square inch, including suction	119.54	118.08	113.7
Temperature, in Fahrenheit degrees, of the feed water when leaving the coil	131.27	126.30	125.5
Temperature, in Fahrenheit degrees, of the feed water when entering the boiler	127.20	123.55	124.0
Temperature of the water of liquefaction when drawn from the reheater, in degrees Fahrenheit	.....	344.35	263.85
Fahrenheit units of heat imparted in the boiler to each pound of feed water	1,092.54	1,096.78	1,096.294
Total number of units of heat imparted in the boiler to the feed water	8,288,008.44	7,975,784.16	8,007,331.376
Product of the total number of double strokes made by the pistons, multiplied by the pressure on the pistons of the pumps	552,513.88	541,278.72	524,839.20
Quotient of the division by the immediately above of the total number of units of heat imparted in the boiler to the feed water	15.0005	14.7351	15.2567

expected from the shortness of the time. The results can be taken as quite decisive of the issue in question.

During all three experiments all the feed water delivered into the boiler was pumped by the feed pump attached to the engine, and was carefully weighed, as during previous tests. The water in the boiler was, as nearly as could be observed, at the same height at the beginning, throughout, and at the end of the experiments. When the reheater was in use the water of liquefaction was drawn off and weighed. Steam was supplied to the reheater by a pipe leading from the main steam pipe near the engine.

About thirty years ago reheaters precisely like the one of the experiments were placed in the receivers of several of the three-cylinder compound engines designed for the French Navy by the celebrated engineer Dupuy De Lôme. They failed to produce any sensible effect. These engines had three duplicate cylinders, horizontal, and placed side by side. The center cylinder received the boiler steam, and exhausted simultaneously into the receivers of the two lateral cylinders.

ECONOMIC RESULTS.

During the experiment the water of liquefaction drawn from the reheater (line 4) was wasted; that is to say, was not pumped back to the boiler; but, in the normal working of the engine, this water is pumped back to the boiler by a special pump for the purpose.

During the experiment, the water of liquefaction from all the jackets of both cylinders was drawn off and wasted; that is, was not pumped back to the boiler, and this water was not intended to be pumped back into the boiler during the normal working of the engine at any time under any circumstances, for the reason that, as the steam received in the jackets was the same as was afterwards used in the cylinders, and as the latter are supplied with sight-feed oil cups, corrosion of the inner surfaces of the boiler might be caused by the oil mingled with the feed water becoming acidified. The same reason requires that no water from the hot well be pumped into the boiler; hence the necessity of taking the whole of the feed water with the exception of what is furnished by the water of liquefaction drawn from the

reheater, from the cold main water and heating it by means of the copper coil placed in the exhaust steam from the large cylinder.

If the lubrication of the cylinders and its valves is done by a mineral oil, as should be the fact and probably is, there can be no danger from its presence in the feed water, as such oil neither acidifies nor saponifies. Apart from this consideration, however, the inner surfaces of the boiler soon become hermetically coated with an impervious scale capable of resisting any attack from any oil, mineral, vegetable or animal, and perfectly protecting the metal beneath. There is, therefore, no valid reason for not feeding the boiler with the high-temperature water of liquefaction from the steam jackets, or with the water from the hot well in the absence of the coil heater. The economic gain by the use of the jacket water cannot be calculated for this particular case, as the weight of that water was not ascertained, nor its temperature. Whatever this gain may be, it will not affect the number of pounds of feed water required per hour per horse power developed by the engine (lines 82, 83 and 84), but it will affect the number of Fahrenheit units of heat consumed per hour per horse power developed by the engine (lines 85, 86 and 87), lessening proportionally the cost of the power in heat or in fuel. In this particular case, probably about 3 per centum of the economy of the engine has been sacrificed to the supposed durability of the boiler. Of course, there is no difficulty at any time of connecting the jacket water with the feed pump, in which case the engine would realize the full fuel economy to which it is entitled.

WEIGHT OF STEAM PRESENT IN THE CYLINDERS AS SHOWN BY THE INDICATOR.

In calculating the weight of steam present in the cylinders at any point, there are taken the weight per cubic foot of the pressure at that point, the number of cubic feet of space from the valves' faces to that point, and the number of single strokes made by the piston; and from the product of these three quantities is deducted the weight of steam cushioned in the cylinder, shown by the product of the weight per cubic foot of the pressure at

the point where the cushioning began, by the number of cubic feet between that point and the valves' faces, and by the number of single strokes made by the piston. The points selected are three in number, namely, the point at which the steam is cut off in the small cylinder, the end of the stroke of the piston of that cylinder, and the end of the stroke of the piston of the large cylinder.

Previous to the point of cutting off the steam in the small cylinder, the steam is supposed to be used without expansion, which is not true. There is expansion, evidenced by fall of pressure, throughout the whole length of the steam pipe, and during the portion of the stroke of the piston of the small cylinder before the cutting off of the steam, but as it cannot be known, the resulting transmutation of heat into the power developed by such expansion has to be neglected.

Apart from the steam liquefied by expansive working in advance of the closing of the cut-off valve, the quantity on line 89 shows the number (21,690.481) of pounds of steam accounted for by the indicator at that point. The enormous difference between this weight and the weight of steam evaporated in the boiler, less the weight of water of liquefaction drawn from the reheater, requires explanation. The weight of steam evaporated in the boiler, minus the weight of the water of liquefaction drawn from the reheater, was (38,229.5 — 3,577.2 =) 34,652.3 pounds. The weight of steam accounted for by the indicator at the closing of the cut-off valve on the small cylinder being 21,690.481 pounds (line 89), the difference 12,961.819 pounds, or 37.405 per centum, is the deficit, due, in the supposed absence of priming, entirely to liquefaction in the steam pipe, to liquefaction in the small cylinder previous to the closing of the cut-off valve, and to the normal liquefaction in the jackets. The water drawn from the jackets not having been weighed, only an estimate of its weight can be given, and, judging from other experiments with other engines, it could not, as it includes the water from the steam pipe as well as the normal water of liquefaction from the jacket, have been less than, say, 10 per centum, leaving (34,652.3 — 3,465 23 =) 31,187 pounds as the weight of steam entering the small cylinder,

and this quantity is to be used in examining the quantities on lines 89 to 95, both inclusive.

It will be remembered that the steam was delivered from the boiler into the jacket of the small cylinder, and thence into that cylinder itself; consequently, this jacket acted as an efficient water trap or separator on the largest scale, so that the steam which did enter the small cylinder, entered it without admixture of water; any primed over water, or water due to loss of heat by external radiation from the steam pipe and jacket was drawn off from the jacket together with the normal jacket water and wasted. No difference of effect could be produced by drawing off from the steam pipe the water of priming, if any there were, and the water of liquefaction due to the external radiation of heat, and so preventing these waters from entering the jacket as was done during Mr. Dean's experiment already referred to.

There will be found that of the steam entering the small cylinder, there was liquefied, when its piston was at the point of cutting off the steam $\left(\frac{31{,}187 - 21{,}690.481 \times 100}{31{,}187} =\right)$ 30.45 per centum.

When this piston was at the end of its stroke, the indicator accounted for 28,367.092919 pounds of steam (line 92), made up of the quantities on lines 90 and 91, the quantity on line 91 being calculable from the data and properly included, as this steam was stricken out of existence by the transmutation of its latent heat into the mass work done by the expansion of the steam after the closing of the cut-off valve. The difference was $\left(\frac{31{,}187 - 28{,}367.092919 \times 100}{31{,}187} =\right)$ 9.04 per centum of the steam entering the small cylinder, which would be considerably diminished could there be included the steam liquefied to furnish the heat transmuted into the mass and molecular work done by the expansion of the steam before the closing of the cut-off valve, and the molecular work done by the expansion of the steam after that closing.

The difference between the 31,187 and 28,367.092919 pounds, namely, 2,819.9 pounds of water of liquefaction, was vaporized

by the heat of the metal of the small cylinder and by the contained heat of that water, during the exhaust stroke of the piston, so that the 31,187 pounds of steam minus the 3,337.32508 pounds (line 91), liquefied to furnish the heat transmuted into the mass work done by the expanding steam alone in the small cylinder, entered the jackets of the large cylinder.

The steam jackets of the small cylinder, though by no means able to prevent an enormous cylinder surface liquefaction previous to the closing of the cut-off valve, doubtless much reduced it, and were able, in conjunction with the heat in the metal of the cylinder, and with the contained heat in the water of liquefaction, to revaporize $(31,187 - 21,690.481 = 9,496.5$; and $\frac{9,496.5 - 2,819.9 \times 100}{9,496.5} = \Big\} 70.3$ per centum of that water by the time the piston reached the end of its stroke. The water of molecular liquefaction suspended in the steam in the form of mist, fog or cloud, line 91, entirely escaped revaporization during the steam stroke. The steam from this revaporized water of liquefaction acted upon the piston and correspondingly increased the power developed in the small cylinder, but far from as economically as if it had been produced in the boiler and worked through the whole stroke of the piston.

In the receiver between the small and large cylinders, the steam exhausted from the former was exposed to the high temperature of the reheating surfaces, which, doubtless, must have entirely revaporized the 3,337.32508 pounds of water of molecular liquefaction in it (line 91), and must additionally somewhat have superheated that steam, so that the exhaust steam from the small cylinder must, on entering the jackets of the large cylinder, have been superheated and 31,187 pounds in weight. Some liquefaction must have taken place in these jackets, due to their external radiation of heat, and to heat transferred to the steam within the large cylinder. Such liquefaction was probably not more than $5\frac{1}{2}$ per centum, making the steam that entered the large cylinder $(31,187 \times 0.945 =)$ 29,472 pounds. Now, the steam accounted for by the indicator at the end of the stroke of the piston of the large cylinder (line 93) was 29,456.539 pounds,

and if there be supposed that this steam was in the dry saturated state with the water of molecular liquefaction due to supplying the heat transmuted into the power developed by the expanding steam barely revaporized, the whole of the steam will have been accounted for.

The preceding distribution of the steam may be summed up as follows:

The available steam evaporated in the boiler was 90.643 per centum of the total evaporation there, the remaining 9.357 per centum being drawn from the reheater.

The water of liquefaction due to all causes in the jackets of the small cylinder has been supposed to be 10 per centum of the available evaporation, leaving 90 per centum of the available evaporation to enter the small cylinder. (This is equivalent to $90.643 \times 0.90 = 81.5787$ per centum of the total boiler evaporation.)

Of this 90 per centum entering the small cylinder, 30.45 per centum was surface liquefied, and found as water of liquefaction in that cylinder at the point of cutting off the steam. (This is equivalent to $81.5787 \times 0.3045 = 24.8407$ per centum of the total boiler evaporation.) The steam jackets under the experimental conditions having failed to prevent liquefaction in the small cylinder, but probably reducing it from, say, 44.55 to 30.45 per centum of the entering steam.

At the end of the stroke of the piston of the small cylinder there was found in it as water of liquefaction—surface and molecular—9.04 per centum of the steam entering it. (This is equivalent to $81.5787 \times 0.0904 = 7.3747$ per centum of the total boiler evaporation.)

By means of the action of the reheater all the steam which entered the small cylinder entered the jackets of the large cylinder, namely, 90 per centum of the available evaporation, or ($90.643 \times 0.90 =$) 81.5787 per centum of the total boiler evaporation, the water of liquefaction in the small cylinder at the end of the stroke of its piston having been revaporized by the reheater.

The water of liquefaction due to all causes in the jackets of

the large cylinder has been supposed to be 5½ per centum of the 90 per centum available evaporation, or ($81.5787 \times 0.055 =$) 4.4868 per centum of the total boiler evaporation.

The steam enters the large cylinder in the dry saturated state, due to the action of the reheater and the jackets of the small cylinder, and continues in that state to the end of the stroke of the piston of the large cylinder, by the action of the jackets thereof.

There is no superheating of the steam in the large cylinder, the reheater and jackets being just able to prevent all liquefaction—surface and molecular—in that cylinder.

The water of liquefaction supposed to be drawn from all of the jackets of both cylinders, is ($8.1579 + 4.4868 =$) 12.6447 per centum of the total boiler evaporation. This estimate cannot be far enough from the truth to practically affect the deductions.

Expanding steam in a working cylinder can only be considered in the dry saturated state at the moment when all the molecular liquefactions it contains are revaporized. It cannot be superheated until then, nor can it be dry.

As the quantity on line 93 is sensibly the quantity that should be there, provided the steam at the end of the stroke of the piston was both dry and not superheated, the assumption is warranted that such was its state, consequently, the quantity (6,006.609477, line 94, minus the quantity 3,337.325080, line 91) 2,669.284397 pounds is included in the quantity on line 93. The fact that the quantity on line 95 is greater than the weight of steam entering the large cylinder proves the above inference.

The experiment shows that the surface liquefaction in the small cylinder of a compound engine when the cut-off valve closes at an early portion of the stroke of the piston is very much greater than in the large cylinder, the cut-off valve of which closes at the same percentage of the stroke of the piston; and this should be the fact, because, under these circumstances, the fall of pressures, and consequently of temperatures, in the small cylinder is much greater than in the large cylinder, and surface liquefaction is due entirely to fall of temperature of the

expanding steam in cylinders. The steam jacket is more efficient, too, with low-pressure steam than with high-pressure steam. In the particular case of the experiment, the jackets of the large cylinder were greatly assisted by the reheater.

As the experiments with the reheater in use and out of use showed that it produced no effect on the economic result of the engine, the performance of the large cylinder would have been lessened somewhat without it, and the performance of the small cylinder would have been correspondingly increased.

Had the water of liquefaction from the steam jackets of each cylinder been weighed and the respective temperatures taken, and had the water of liquefaction from the steam pipe been weighed and its temperature taken, these data, in combination with what was obtained, would have enabled a very complete and satisfactory investigation of the experiment to be made. The experiment, however, was not undertaken for any scientific object; it was made for a purely commercial purpose, to ascertain whether the requirements of a contract had been fulfilled, and, as far as that went, every measured quantity was determined with the utmost precision and skill, and can be depended on as absolutely exact. The practical result showed that the engine did its work with a rarely equaled economy and efficiency, which makes an examination of the means producing such results so much the more valuable and interesting, even with the lacunes impossible to be now supplied.

DUTY.

There were consumed during the trial 3,833 pounds of first quality semi-bituminous coal, burnt at the rate of 7.9647 pounds per hour per square foot of grate surface, and 0.1659 pound per hour per square foot of heating surface; the ratio of the heating to the grate surface being 48 to 1. Each pound of crude coal in its merchantable state vaporized under the experimental conditions 9.9737 pounds of water.

The duty of the system as a whole, including combined efficiencies of engine, boiler, coal, etc., determined by dividing the number of foot pounds of work done by the pistons of the

pumps by the number of pounds of crude coal consumed, was 126,000,000 pounds of water raised one foot high by 100 pounds of coal.

An account of another and later experiment on this engine, by Mr. F. W. Dean, will be found on page 465 of the May, 1893, number of this JOURNAL, and may be studied with advantage in connection with the data and deductions of the present paper.

TABLE CONTAINING THE DATA AND RESULTS OF THE EXPERIMENT MADE WITH THE COMPOUND STEAM-JACKETED CONDENSING PUMPING ENGINE SUPPLYING THE CITY OF NEWTON, MASSACHUSETTS, WITH POTABLE WATER.

DATE OF THE EXPERIMENT, APRIL 30, 1892.

TOTAL QUANTITIES.

1, Duration of the experiment, in consecutive hours	10.
2, Total number of double strokes made by the pistons of the steam cylinders and of the pumps	22,617.
3, Total number of pounds of feed water consumed	38,229.5
4, Total number of pounds of water of steam liquefaction drawn from the reheater (included in the feed water)	3,577.2
5, Total number of foot-pounds of work done by the steam pistons, including overcoming the back pressure	5,562,065,025.
6, Total number of foot-pounds of work done by the pump pistons	4,807,976,382.
7, Total number of Fahrenheit units of heat put into the feed water	42,243,296 939671
8, Fraction of the work done by the steam pistons, done by the pump pistons	0.864423.
9, Number of foot-pounds of work done by the steam pistons per Fahrenheit unit of heat expended	131.6674
10, Number of foot-pounds of work done by the pump pistons per Fahrenheit unit of heat expended	113 8163

ENGINE.

11, Number of double strokes made per minute by the pistons	37.695
12, Barometer, in inches of mercury at 72° Fahrenheit	30.225
13, Pressure of the atmosphere, in pounds, per square inch above zero	14.800
14, Steam pressure in boiler, in pounds, per square inch above atmosphere	122.66
15, Steam pressure in boiler, in pounds, per square inch above zero	137.46

16, Steam pressure in steam pipe, just in front of the throttle valve near the engine, in pounds, per square inch above atmosphere	119.90
17, Steam pressure in steam pipe, just in front of the throttle valve near the engine, in pounds, per square inch above zero	134.70
18, Vacuum in condenser, in inches of mercury	27.10
19, Back pressure in condenser, in pounds, per square inch above zero	1.506
20, Fraction of the stroke of the pistons of both cylinders at which the steam is released	0.98
21, Fraction of the stroke of the pistons of both cylinders at which the steam is cushioned	0.08
22. Fraction completed of the stroke of the piston of the small cylinder when the steam was cut off	0.20
23, Fraction completed of the stroke of the piston of the large cylinder when the steam was cut off	0.25
24, Number of times the steam was expanded in the small cylinder	4.313041
25, Number of times the steam was expanded in the engine	17.458914

TEMPERATURES.

26, Temperature, in Fahrenheit degrees, of the air in the engine room	72.
27, Temperature, in Fahrenheit degrees, of the steam in the boiler	351.42
28, Temperature, in Fahrenheit degrees, of the steam in the steam pipe just in front of the throttle valve near the engine	349.86
29, Temperature, in Fahrenheit degrees, of the feed water when entering the coil for heating it	59.
30, Temperature, in Fahrenheit degrees, of the feed water when leaving the coil for heating it	122.
31, Number of Fahrenheit units of heat imparted by the exhaust steam of the engine to the feed water in the coil heater	63.1476
32, Temperature, in Fahrenheit degrees, of the feed water when entering the boiler	116.
33, Temperature, in Fahrenheit degrees, of the water of liquefaction when drawn from the reheater	322.7
34, Temperature, in Fahrenheit degrees, of the hot well	98.
35, Temperature, in Fahrenheit degrees, of the water in the main	48.
36, Temperature, in Fahrenheit degrees, of the steam at the end of the stroke of the piston of the large cylinder	181.7

MAIN PUMPS.

37, Water pressure, by gauge, in chamber of delivering valves of the main pumps, in pounds per square inch..... 107.73

38, Pressure corresponding to the water column between the gauge and the water level in the pump well, in pounds per square inch..... 8.77

39, Pressure upon the pistons of the pumps, in pounds per square inch 116.50

NOTE.—The pressure in the pump chamber between the receiving and delivering valves was sensibly the same as the pressure shown by the gauge on the delivering valve chamber.

STEAM PRESSURES IN SMALL CYLINDER.

40, Pressure on the piston of the small cylinder at the commencement of its stroke, in pounds per square inch above zero..... 136.675

41, Pressure on the piston of the small cylinder at the point of cutting off the steam, in pounds per square inch above zero..... 128.862

42, Pressure on the piston of the small cylinder at the end of its stroke, in pounds per square inch above zero..... 31.000

43, Back pressure against the piston of the small cylinder, exclusive of the cushioning, in pounds per square inch above zero..... 27.500

44, Back pressure against the piston of the small cylinder, inclusive of the cushioning, in pounds per square inch above zero..... 28.000

45, Back pressure against the piston of the small cylinder at the point where the cushioning commenced, in pounds per square inch above zero..... 27.250

46, Indicated pressure on the piston of the small cylinder, in pounds per square inch..... 45.475

47, Net pressure on the piston of the small cylinder, in pounds per square inch..... 43.4118

48, Total pressure on the piston of the small cylinder, in pounds per square inch above zero..... 70.500

49, Pressure of the expanding steam alone on the piston of the small cylinder after the closing of the cut off, in pounds per square inch above zero..... 58.400

STEAM PRESSURES IN LARGE CYLINDER.

50, Pressure on the piston of the large cylinder at the commencement of its stroke, in pounds per square inch above zero..... 28.0

51, Pressure on the piston of the large cylinder at the point of cutting off the steam, in pounds per square inch above zero..... 23.5

52, Pressure on the piston of the large cylinder at the end of of its stroke, in pounds per square inch above zero..... 7.6

53, Back pressure against the piston of the large cylinder, exclusive of the cushioning, in pounds per square inch above zero..... 2.8

54, Back pressure against the piston of the large cylinder, inclusive of the cushioning, in pounds per square inch above zero..... 3.0

55, Back pressure against the piston of the large cylinder at the point where the cushioning commenced, in pounds per square inch above zero..... 2.6

56, Indicated pressure on the piston of the large cylinder, in pounds per square inch..... 12.925

57, Net pressure on the piston of the large cylinder, in pounds per square inch..... 12.41625

58, Total pressure on the piston of the large cylinder, in pounds per square inch above zero..... 15.473

59, Pressure of the expanding steam on the piston of the large cylinder, in pounds per square inch above zero... 15.925

60, Mean pressure of the steam between the commencement of the stroke of the piston and the point of cutting off the steam in the large cylinder, in pounds per square inch above zero..... 26.5

61, Mean pressure of the steam between the point of cutting off the steam and the end of the stroke of the piston of the large cylinder, in pounds per square inch above zero..... 12.42747

EQUIVALENT STEAM PRESSURES FOR THE LARGE CYLINDER.

62, Indicated pressure, in pounds per square inch, that would be on the piston of the large cylinder were the indicated pressure on the piston of the small cylinder divided by the ratio of the net areas of these pistons and the quotient added to the experimental indicated pressure on the piston of the large cylinder..... 24.13837

63, Net pressure, in pounds per square inch, that would be on the piston of the large cylinder were the net pressure on the piston of the small cylinder divided by the ratio of the net areas of these pistons and the quotient added to the experimental net pressure on the piston of the large cylinder..... 23.12111

64, Total pressure, in pounds per square inch above zero that would be on the piston of the large cylinder to correspond to the total horses power developed by the engine..... 26.74718

65, Back pressure in pounds per square inch above zero that would be against the piston of the large cylinder corresponding to its experimental back pressure plus the difference in pounds per square inch between the back pressure, exclusive of the cushioning, against the piston of the small cylinder and the mean pressure between the commencement of the stroke of the piston of the large cylinder and the point of cutting off the steam in the large cylinder	2.8668

HORSES POWER.

66, Indicated horses power developed in the small cylinder	117.768470
67, Net horses power developed in the small cylinder	112.425316
68, Total horses power developed in the small cylinder	182.576737
69, Total horses power developed in the small cylinder by the expanding steam alone	120.992697
70, Indicated horses power developed in the large cylinder	135.744890
71, Net horses power developed in the large cylinder	130.401771
72, Total horses power developed in the large cylinder by the annular surface of its piston remaining after deducting from the area of that piston the area of the piston of the small cylinder	98.335638
73, Total horses power developed in the large cylinder by the expanding steam acting upon the annular surface of its piston remaining after deducting from the area of that piston the area of the piston of the small cylinder	102.444141
74, Aggregate indicated horses power developed by the engine	253 513360
75, Aggregate net horses power developed by the engine	242.827090
76, Aggregate total horses power developed by the engine	280.912375
77, Aggregate total horses power developed by the expanding steam alone	223.436838
78, Horses power exerted by the pistons of the main pumps	242.827090
79, Fraction which the horses power exerted by the pistons of the main pumps is of the total horses power developed by the engine	0.864423
80, Fraction which the horses power exerted by the pistons of the main pumps is of the indicated horses power developed by the engine	0.957847
81, Horses power exerted in overcoming all the frictions of the engine, and in working the air pump and the feed pump	10.686273

ECONOMIC RESULTS.

82, Pounds of feed water consumed per hour per indicated horse power developed by the engine	15.079876

83. Pounds of feed water consumed per hour per net horse power developed by the engine	15.743507
84. Pounds of feed water consumed per hour per total horse power developed by the engine	13.609048
85. Fahrenheit units of heat consumed per hour per indicated horse power developed by the engine	16,663.144278
86. Fahrenheit units of heat consumed per hour per net horse power developed by the engine	17,396.451500
87. Fahrenheit units of heat consumed per hour per total horse power developed by the engine	15,037.891065

WEIGHT OF STEAM PRESENT IN THE CYLINDERS, AS SHOWN BY THE INDICATOR.

89. Pounds weight of steam in the small cylinder at the point of cutting off the steam	21,690.481010
90. Pounds weight of steam in the small cylinder at the end of the stroke of its piston	25,029.767839
91. Pounds weight of steam liquefied in the small cylinder to furnish the heat transmuted into the power developed in that cylinder by the expanding steam alone	3,337.325080
92. Sum of the two immediately preceding quantities	28,367.092919
93. Pounds weight of steam in the large cylinder at the end of the stroke of its piston	29,456.539022
94. Pounds weight of steam liquefied in the large cylinder to furnish the heat transmuted into the power developed in that cylinder by the expanding steam, plus the pounds weight of steam liquefied in the small cylinder to furnish the heat transmuted into the power developed in that cylinder by the expanding steam alone	6,006.609477
95. Sum of the two immediately preceding quantities	35,463.148499

FAST OCEAN STEAMSHIPS.

By Francis Elgar, Esq., L. L. D., F. R. S. E.

[Read at the Summer Meeting of the Thirty-fourth Session of the Institute of Naval Architects, July 11, 1893.]

When the present meeting was arranged for I was asked to read a paper upon the above subject, with special reference to vessels of the largest type, such as the new Cunard steamships *Campania* and *Lucania*, for which I am the consulting naval architect. The Secretary informed me that the subject was considered very suitable to the occasion, especially as no paper upon it has been contributed to our Transactions since the late Mr. William John—one of the ablest and most valued members this Institution has had during the third of a century it has existed—read one upon "Atlantic Steamers," in 1886.

Our present knowledge and experience of many of the conditions that limit or influence speed at sea, and of their separate or combined effects, are by no means exact or exhaustive. In considering the general question of the proportions, power, and detailed arrangements requisite for a ship in order to absolutely insure that the highest possible average speed shall be obtained and kept up over an indefinite number of long ocean voyages, under the restrictions imposed by the existing conditions of ship, engine, and boiler construction, harbor and dock accommodation, &c.—a question which would be a mere matter of calculation if all the circumstances affecting it were fully and accurately known—we find that the answer depends ultimately, to a great extent, upon personal judgment, and is open to be materially affected by hopefulness or imagination. It would be unprofitable to attempt to enter upon such a speculation here, and I resist the temptation to do so. It might, perhaps, be more useful and

FIG. 1.

TWIN SCREW STEAMER "CAMPANIA"

— PROFILE —

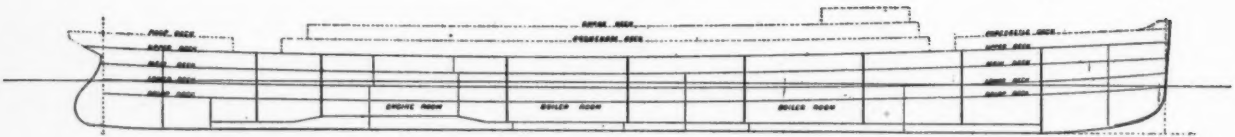


FIG 2

SINGLE SCREW & PADDLE STEAMER

GREAT EASTERN

— PROFILE —

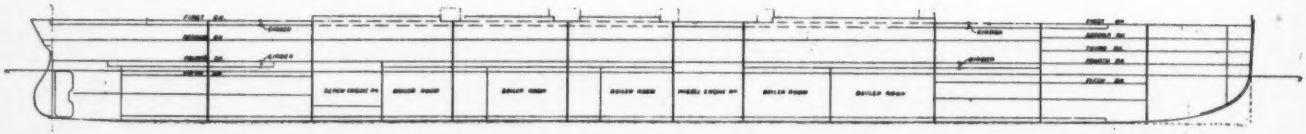


FIG. 3.

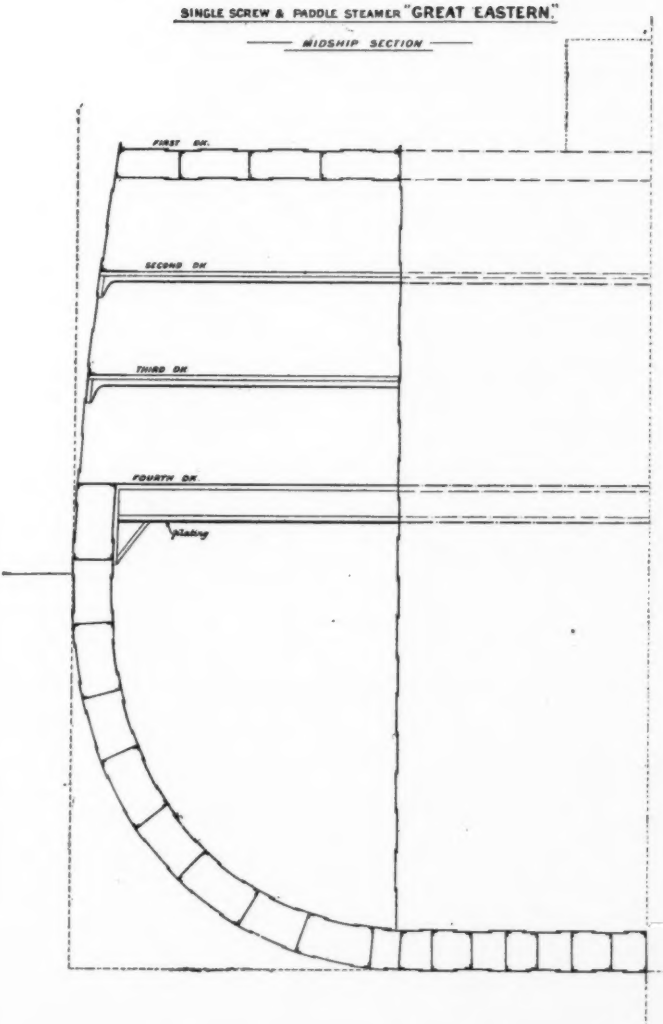
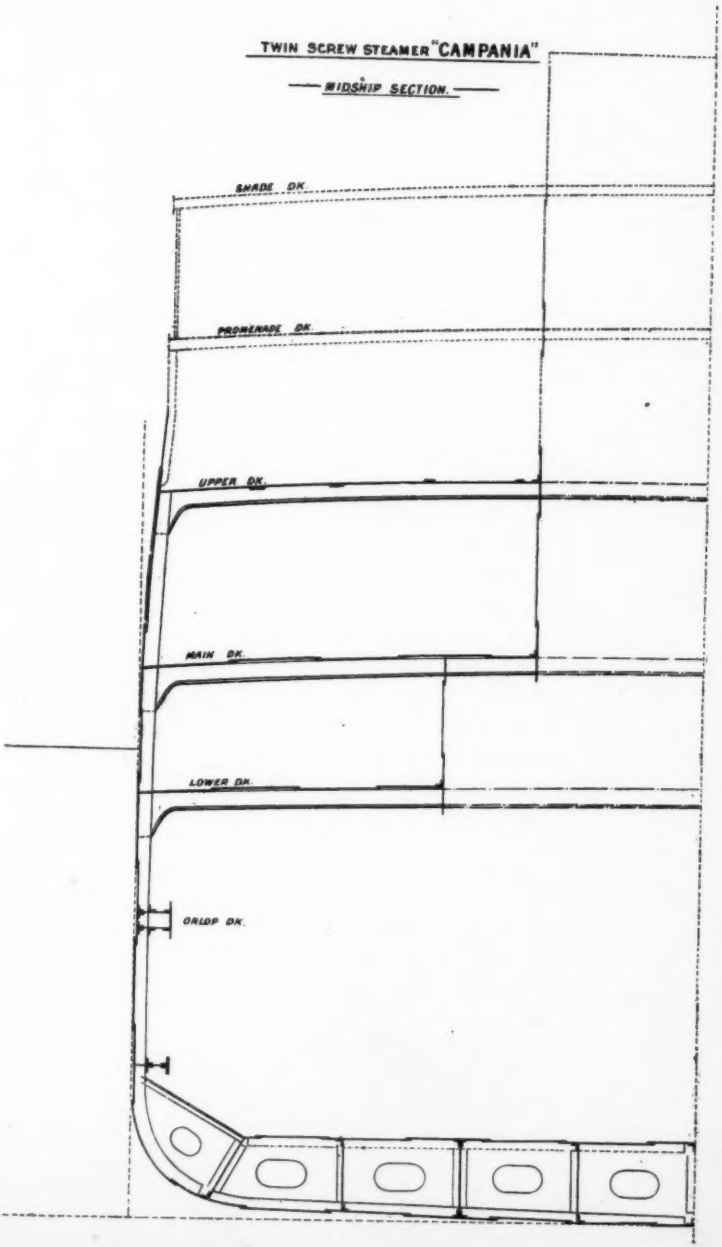

SINGLE SCREW & PADDLE STEAMER "GREAT EASTERN."
MIDSHIP SECTION
FIRST DK.
SECOND DK.
THIRD DK.
FOURTH DK.
plating

FIG. 4.


TWIN SCREW STEAMER "CAMPANIA"
MIDSHIP SECTION.
SHADE DK.
PROMENADE DK.
UPPER DK.
MAIN DK.
LOWER DK.
ORLOP DK.

appropriate to call attention to a few of the principal points that affect speed at sea, and some of the directions in which theory and experience show the way to continued improvement.

The *Great Eastern* is the most wonderful instance the world has seen of attempts to obtain high speed over long distances at sea. She was designed forty years ago, and her name is probably associated in the minds of most people only with errors and disaster. Our Transactions contain but little about her, although her constructor, Mr. J. Scott Russell, was one of the founders of this Institution, and was for over twenty years one of its most prominent members. It is universally known that she was remarkable for her enormous size; but it is often forgotten that there was anything else about her worthy of notice or admiration. Every new ship that is built of greater dimensions than her predecessors is naturally compared in size with the *Great Eastern.* The *Great Eastern* was remarkable, however, not only for the vastness of her proportions, but also for the thought, care, and skill employed in her design and construction, and for the extent to which problems relating to high speed upon the longest ocean voyages—some of which are, at times, thought to be peculiarly modern—were understood and worked out by her designer. I have thought it might be interesting to compare the latest large steamships with the *Great Eastern* more in detail than is usually done, and to bring into the comparison not merely size, but some of the leading details of design and construction.

In the latter part of 1851 Mr. Brunel began to work out his idea of a great ship for the Indian and Australian trade. He spent two years in inquiries, investigations, and calculations relating to the numerous problems—many of them quite novel then, though more familiar now—that were raised by such a tremendous stride in advance of all former experience and ideas. The magnitude of the stride was as great as would now be involved by the construction of a ship 1,200 feet long and 30 to 35 knots speed.

The following is a comparative statement of particulars of the *Great Eastern* and *Campania:*

	Great Eastern.	*Campania.*
	ft. in.	ft. in.
Length over all, ...	692 0	622 0
Length between perpendiculars, . .	680 0	600 0
Breadth moulded, ...	82 2	65 0
Depth moulded to upper deck, . .	58 0	41 6
	Tons.	Tons.
Register tonnage, gross, . . .	18,915	12,950
Register tonnage, under deck, . .	18,837	10,267
	ft. in.	ft. in.
Load draught, ...	30 0	27 0
Passenger accommodations, 1st class, .	800	600
Passenger accommodations, 2d class, .	2,000	300
Passenger accommodations, 3d class, .	1,200	700
Indicated horse power of engines, .	ab't 8,000	ab't 30,000
Speed at sea in knots at full power, .	14 to 14½	22 to 23

The *Great Eastern* had two separate sets of propelling machinery—one driving a screw propeller, and the other a pair of paddle wheels. The screw engines were the most powerful, and could indicate up to 4,500 H.P. at sea. The paddle engines indicated 3,500, so that the maximum I.H.P. was about 8,000. This power gave a speed of 14 to 14½ knots at sea, with a coal consumption of about 400 tons per day. There were four cylinders to each set of engines, those of the screw engines being 7 feet in diameter, with a stroke of 4 feet, and those of the paddle engines 6 feet 2 inches in diameter, with a stroke of 14 feet. The screw was four-bladed, and had a diameter of 24 feet, with 44 feet pitch. The paddle wheels were 56 feet in diameter. The working steam pressure appears to have been about 20 pounds, and steam was cut off in the cylinders at one-third of the stroke. The boilers were tubular, and of the square box type, and they were double-ended. There were ten boilers in all, 18 feet long, 17 feet 6 inches wide, and 14 feet high, with 112 furnaces.

The *Campania* has also two separate sets of propelling machinery, but in her case they drive twin screws. The propelling power is fully three and a half times that of the *Great Eastern*, and the speed more than 50 per cent. greater. This increase in power and speed is obtained with a daily coal consumption that

is but little in excess of the *Great Eastern's.* There are five cylinders to each set of the *Campania's* engines, and they work three cranks. There are two high-pressure and two low-pressure cylinders, and the high-pressure cylinders are placed upon the low pressure. The cylinders are 37 inches, 79 inches, and 98 inches in diameter respectively, with 69 inches stroke. The screw propellers are smaller than that of the *Great Eastern.* The boilers are thirteen in number, twelve being double-ended, and one single ended, with 100 furnaces, or 12 furnaces less than in the *Great Eastern.*

Figs. 1 to 4 show the main structural features of the *Great Eastern* and the *Campania.* One of the chief differences is that the main structure of the hull is much deeper in the former vessel than in the latter. The *Great Eastern* was a flush-decked ship, with no erections on deck, except a few small houses at the middle line, shown by dotted lines; and the moulded depth from this deck was 58 feet, making the vessel 11.7 depths in length. The *Campania* carries upon her upper deck—in conformity with the type of vessels that has been developed for the accommodation of the largest number of passengers—two tiers of decks. The first, or promenade, deck consists of forecastle, poop, and midship deck for passengers, nearly 400 feet long. This deck is practically continuous, the midship part being separated from the forecastle and poop only by a small break at each end. Upon the promenade deck a large amount of first-class passenger accommodation is provided, which includes library, drawing and music rooms, smoking room, twenty staterooms, &c. The second, or shade, deck is carried right across the promenade deck as a shelter to the passengers, and it extends fore and aft over the whole length of that deck. Upon it are carried the boats, cabin accommodation for the captain and officers, chart room, wheel house, &c.

The moulded depth from the upper deck of the *Campania* is 41 feet 6 inches, making 14½ depths in length. The moulded depth from the shade deck is 59½ feet, which is only 1½ feet more than the moulded depth of the *Great Eastern* from the upper deck.

Apart from this difference in moulded depth, the main features of the structural design of the hull are very similar in the two cases. There are several complete iron or steel decks, the upper one being of great extra strength,* a bottom made very strong by means of inner bottom plating and longitudinals, and a very similar amount and arrangement of internal subdivision of the hull by water-tight bulkheads.

The framing of the hull was entirely longitudinal in the *Great Eastern*, and the inner bottom was carried up as shown in Fig. 3. The longitudinals were 2 feet 10 inches deep, and $\frac{1}{2}$ inch thick. They were about 2 feet 6 inches apart on the flat of the bottom, and 5 feet apart from the bottom to a height of 35 feet. The scantlings of the hull seem to have been arranged upon a simple principle, for Mr. Scott Russell says, in his work on "Naval Architecture," page 394, "there is one thickness of plates, $\frac{3}{4}$ inches, for skin, outer and inner; one thickness for internal work, $\frac{1}{2}$ inch; one size of rivet, $\frac{7}{8}$ inch; one pitch, 3 inches, and one size of angle iron, 4 inches by 4 inches by $\frac{5}{8}$ inch."

The shell plates, which were $\frac{3}{4}$ inch thick, were only 10 feet long and 2 feet 9 inches wide, being, it may be presumed, the largest obtainable at that time. The weight of one of these plates would be under $7\frac{1}{2}$ cwts. The bulkhead plates, which were $\frac{1}{2}$ inch thick, were about 9 feet long and 3 feet wide. The progress since made in the manufacture of ship plates is shown by the fact that the shell plates of the main portion of the hull of the *Campania*, which are $\frac{7}{8}$ inch thick, average over 26 feet in length, 5 feet 3 inches in breadth, and 45 cwts. in weight. Mr. Scott Russell says, "The *Great Eastern* was entirely built with single riveting, the double riveting being at the butts mostly." We have since learned that much can be done to increase the strength and prevent the undue straining of such a structure as a ship's hull by extra riveting. In the *Campania* three of the edges of the bilge strakes, and the top edges of the upper strakes of plating on each side, are treble riveted, and the remainder are double riveted; and all the butts, which are lapped, as in the

* In the *Great Eastern* this deck is cellular in construction, and consists of longitudinal girders plated at the top and bottom with $\frac{1}{2}$-inch plates.

Teutonic and *Majestic*, are quadruple riveted, except at the extreme ends, where they are treble riveted.

Mr. Brunel communicated his views respecting a great steamer for the Indian trade to the directors of the Eastern Steam Navigation Company, after discussing them with Mr. Scott Russell and others. This company was formed in 1851 to convey mails, passengers, &c., by the overland route between England and India and China, with a branch to Australia. The Government, however, gave the contract for the whole service to the Peninsular and Oriental Company in March, 1852, and the Eastern Steam Navigation Company found itself in the position of being unable to carry out the objects for which it had been incorporated.

They then turned their attention to the main oversea route followed by British commerce round the Cape towards India, China and Australia, which was nearly the same as far as Ceylon. "On the fact of this great pathway of commerce they grounded, and not without plausible reasons, their scheme for the profitable employment of various vessels of gigantic size between England and Ceylon, from which place smaller vessels were to diverge to the other parts of India, as well as to China, Japan and Australia; the intention, however, being to despatch their first great vessel, when ready, direct to Calcutta, Sydney and Melbourne."*

Mr. Brunel reported as follows in March, 1853, to a committee appointed by the directors to confer with him upon the design of the great ship: "The dimensions arrived at by calculation for this ship would be, in round numbers, 670 feet long, 80 feet beam. This sized vessel would combine most of the advantages which we seek to obtain. It would carry coal to Diamond Harbor (in the Hooghly), and back to Trincomalee; it would afford room for about 800 separate cabins, larger than those now fitted up in packet ships, with large saloons capable of accommodating 1,000 or 1,500 first and second-class passengers, and would carry 3,000 tons weight of cargo, without making any allowance for

* History of Merchant Shipping and Ancient Commerce, vol. iv, p. 488. (W. S. Lindsay.)

that increase of speed proportionate to the mere increase of size, of which we see every day fresh proof; the average speed of the ship, with the proposed power of engine and calculated consumption of coal, would be 14 knots at the average, making the passage out in 34½ days, say 36; but, with that increased speed which has been shown to take place with increased dimensions, we may speculate upon the voyage being performed in 30 days.

"This same vessel, fitted up for the Australian voyage and loaded deeper, would carry coals to Australia and back; would take out 3,000 passengers easily, and a small amount of cargo only, but could bring back any amount that could be conveniently collected; or if provision were made for taking in 3,000 or 4,000 tons of coal in Australia, that additional amount of cargo might be taken on the passage out. The passage out to Port Philip should be made easily in 36 days, and home by Cape Horn in the same time."

Mr. Brunel was authorized to continue his communications with shipbuilders and engineers and to invite tenders. The contracts for building the vessel, as slightly enlarged to 680 feet by 82 feet, were signed at the end of 1853. The hull and paddle engines were given to Messrs. Scott Russell & Co., of London, and the screw engines to Messrs. James Watt & Co., Soho Works, near Birmingham. Mr. Scott Russell wrote as follows to "The Times" on April 20, 1857: "My share of the merit and responsibility is that of builder of the ship for the Eastern Steam Navigation Company. I designed her lines and constructed the iron hull of the ship, and am responsible for her merits or defects as a piece of naval architecture. I am equally responsible for the paddle-wheel engines. * * * It is to the company's engineer, Mr. I. K. Brunel, that the original conception is due of building a steamship large enough to carry coals sufficient for full steaming on the longest voyage. He, at the outset, and long before it had assumed a mercantile form, communicated his views to me, and I have participated in the contrivance of the best means to carry them into practical effect."

Sufficient capital was raised to build the ship, which the directors stated could be completed in eighteen months, and

"which would, undoubtedly, according to all existing experience, pass through the water at a velocity of 15 knots an hour, with a smaller power in proportion to tonnage than ordinary vessels now require to make 10 knots." The first plates of the flat portion of the bottom were laid on May 1, 1854; but it was not till November 3, 1857, that she was ready for launching. The lauching operation was, as is well known, a disastrous failure, and the vessel was not got into the water till January 31, 1858. The cost of the launch is said to have amounted to £120,000, and the company's funds became exhausted. The vessel lay in the Thames for more than a year with all work stopped upon her, when she passed into the hands of a new company called the "Great Ship Company." She made her first steam trial in September, 1859; and as the trade for which she was originally intended could only be worked, if at all, by a number of such ships making voyages at regular and not too long intervals, with smaller vessels in the Indian Ocean to distribute the freight and passengers among the Eastern ports, this idea had to be given up. She was accordingly put into the Atlantic trade, and made nine Transatlantic voyages between 1860 and 1863. Upon the fourth voyage, with 400 passengers on board, the rudder head was twisted off and the paddle wheels damaged in a heavy gale, and the vessel was obliged to put back to Queenstown. On another voyage outwards to New York she passed over a reef of rocks off Long Island Sound, which tore the bottom plating open in ten places and made one hole 80 feet long and 10 feet wide. Her very complete subdivision protected her against anything more than local damage, and most of the passengers landed in ignorance of an accident which would probably have proved fatal to any other existing vessel.

The *Great Eastern's* speed upon the Atlantic sometimes reached 14½ to 15 knots average during one day, with a draught of water on leaving port of about 28 feet. Upon one voyage her speed averaged 13¾ knots outwards and 14 knots homewards. The highest average speeds upon the Atlantic in 1852, when the *Great Eastern* was designed, were about 10 knots. It will thus

be seen that the anticipations with regard to her speed were not without justification.

Owing to the impossibility of working upon the Atlantic at a profit, the ship passed into other hands, and was afterwards occupied chiefly in cable-laying. After the demand for her employment in this work fell off, she lay many years, uncared for, in Milford Haven, and was at last sold and broken up.

Mr. W. S. Lindsay says: "Though far from realizing the expectations once entertained with regard to speed* and small consumption of fuel, her failure is mainly to be attributed to the fact that, at the time she was constructed, there were no lines of traffic on which a vessel of such huge capacity could procure, with despatch, the amount of freight or passage money necessary to insure a profit."

The *Great Eastern* was a failure commercially; but, from a mechanical point of view, she was in all her main features successful to a degree that was marvelous, when compared with the standard of the time. Mr. Brunel did not know the "law of comparison," taught us by the late Mr. Froude, which shows how the power required to drive a ton of displacement at a given speed in a small ship becomes reduced as the dimensions are increased in similar ships; but he well knew the fact that the proportion of power to displacement becomes less as a ship is increased in size, for the same speed. He acted upon this principle in 1836 in the design of the famous Atlantic steamer *Great Western*, and carried it to an extreme length in the design of the *Great Eastern*.

Mr. Brunel said: "I never embarked in any one thing to which I have so entirely devoted myself, and to which I have devoted so much time, thought and labor, and on the success of which I have staked so much reputation."† This will be understood when the responsibilities of the designer of such a vast and novel work are considered. Almost everything had to

* The expectations with regard to speed appear to have been fairly realized, though with a consumption of coals that greatly exceeded Mr. Brunel's estimates.

† "The Life of Isambard Kingdom Brunel, Civil Engineer." By Isambard Brunel. (Longmans, Green & Co. 1870.)

be thought out and arranged for, with but very little help from existing ideas and experience. Mr. Brunel said in one of his memoranda: "Every part has to be considered and designed as if an iron ship had never before been built; indeed, I believe we should get on much quicker if we had no previous habits and prejudices on the subject."

The lines were designed by Mr. Scott Russell upon his wave-line principle. The cellular construction of the hull, and the inner bottom, with the very complete internal subdivision into watertight compartments—an arrangement that would fulfil the most modern and stringent requirements, as laid down in the recent report of the Bulkhead Committee—were due to Mr. Brunel. Investigations upon the rolling of ships, with special application to the design of the *Great Eastern*, were made for Mr. Brunel by his friend, the late Mr. William Froude; and I think, we probably owe Mr. Froude's important contributions upon the Rolling of Ships to our Transactions to his association with Mr. Brunel in this matter. Mr. Froude employs in his first paper on the Rolling of Ships (Vol. II of Transactions, pp. 219–221), data obtained from rolling experiments made with a model of the *Great Eastern*. Mr. Brunel also wanted to experiment upon the relative resistances in water of clean copper and painted iron surfaces, with the view, at first, of having the outer shell of the *Great Eastern* of wood, sheathed with copper. He appears to have finally settled upon iron, because of the difficulty of devising any means of dealing exhaustively with the question, and because he doubted whether, with a very long surface, the smoothness would much affect the total resistance.

Having dealt at much greater length with the subject of the *Great Eastern* than I would otherwise have done, because of the want of information in our Transactions respecting the design and performances of the most wonderful piece of naval architecture ever projected, I will pass on to some of the general questions involved by the growing demand for increased speed at sea.

There are already several ships that can cross the Atlantic at an average speed of over 20 knots, or 23 statute miles per hour.

The *Campania* crossed from Sandy Hook to Queenstown, on her first voyage in May last, at an average of 21.3 knots, and during one day she averaged 22.3 knots. These speeds are a little over 24½ and 25½ statute miles per hour, respectively. It is thus already possible to cross the Atlantic at as great a speed as journeys of the same length could be made on land by all but the fastest railway trains. The Canadian Pacific Railway, for instance, takes 5 days 19 hours between Montreal and Vancouver, a distance of 2,906 miles, giving an average speed of a little less than 21 miles per hour.

There are various standards by which the speeds of ships are judged. We have the trial speeds, which may be determined by a series of runs over a measured mile, or by runs over various distances in smooth water at sea; we have runs for a certain length of time in ordinary weather at sea; and, finally, we have the average speed which a ship can maintain, year after year, over the whole of her voyages in all seas and all weathers.

The last named is the kind of speed now under consideration. Among the conditions essential to high speed, as thus defined, are: (1) Great size of ship; (2) a form suitable for driving easily at high speeds over heavy seas without shipping heavy water, or lifting the propellers sufficiently to cause racing; (3) deep draught of water; (4) steadiness in a sea way; (5) great strength of structure and of machinery; (6) a large proportion of boiler power, so as to enable a full supply of steam for the engines to be easily kept; (7) a full and well-regulated supply of air to the furnaces.

Effect of Size of Ship upon Speed.—The well-known effect of size upon speed in still water, which is explained by Froude's "Law of Comparison," is not the only one that gives great size of ship an advantage at sea. There is an additional advantage at sea, in a large ship, due to the waves being smaller in proportion to the dimensions of the ship, and to the pitching motion being less in a heavy sea as a ship is increased in size. The speed of a ship at sea approximates more nearly to that obtained in still water, with the same propulsive power, the larger she is made. No doubt length is the principal element

of size in this respect, but depth, or draught of water, is also very important. Whatever might be the speed obtained with a ship on trial in smooth water, the extent to which her average sea speed would afterwards approach this would depend very greatly upon her size. A striking proof of this is seen in the increasing regularity—as distinct from increase of speed—with which steamers make their voyages as their size is increased. The variations in length of voyage from the average become less with increase of size. The effect of size upon speed is the same in sailing ships as in steamers, and is shown by the reduction in the average times of voyages to Australian, and other far-distant ports, to which large sailing ships trade, as size is increased.

Effect of Form upon Speed.—The full effect of form upon average speed at sea, over long voyages and in all weathers, cannot be measured by still-water trials. The form that gives the best results in still-water trials, with any size of ship, does not necessarily give the best results at sea. It is sometimes said as an objection to model experiments, such as Mr. Froude taught us to make, and to still-water trials—which belong to the same category—that they do not tell us what the speed will be at sea, or what is the best form for speed at sea. The reply is that Mr. Froude never said they would. The late Mr. Froude always explained that his experiments merely related to speed in absolutely smooth water; and Mr. R. E. Froude reminded this Institution in 1883 (see Vol. XXIV of Transactions, page 161) that his father was very particular in pointing out this qualification. He said, in speaking of the comparative resistance of long and short ships: "A diminution of the fulness of the ends, and concentrating the displacement in the middle of the ship, and removing it from the ends, is certainly likely to make the ship pitch, and it is not only objectionable on that ground, but the performance of such a ship in a seaway would, from that reason, be comparatively less favorable than in still water, because the pitching must certainly rather tend to increase the resistance. So that it is probable the gain in the performance which we find

in trials to be realized by ships with fine ends in still water is greater than they would evince in practically working at sea."

If it ever be assumed that the best form of ship for a still-water speed trial is the best form for speed at sea, as herein defined, or that the sea speeds will bear a fixed relation to the trial speeds, Mr. Froude must not be blamed for the fallacy. Mr. Froude has given us a wonderfully ready and exact means of determining the resistances of ships in smooth water; but the designer is necessarily left to his own judgment and experience as to the modifying effects of bad weather and heavy seas—which are all-important upon such voyages as Atlantic steamers are designed for. I have crossed the Atlantic seven times, but it has never been my lot to find there a state of sea which even approximately resembled the conditions of a still-water trial. With fine lines forward and aft, such as would be most favorable to trial speeds, the speeds at sea might be considerably reduced; and it would be easy to improve the speed upon trial of some of the fast Atlantic steamers at the expense of their subsequent speeds at sea. The improvement of existing forms in suitability for Atlantic seas must, in my judgment, be looked for more in knowledge and experience of what such a sea requires than in mere still-water experiments. Some of the present steamers maintain an average speed of not more than a knot less than they obtain on trial with the same power, showing that their forms are almost as well adapted for speed in ordinary seas as in smooth water; and it would be easy, as I have said, if speed upon smooth-water trials were the crucial test, to considerably increase the latter at the expense of the former.

One of the chief points in connection with the form best adapted for sea speed is that it should offer resistance to pitching. The fineness of ends that would give the best results in smooth water requires to be corrected by the fulness necessary to prevent undue pitching. It is only the judgment and experience of the naval architect that can decide where the line is to be drawn between the two directions. If he err on the side of fineness, as tempted perhaps by the desire to obtain the highest possible still-water results, he will lose in speed when there is

any sea; and if on the side of fulness, he will lose by excess of resistance in smooth water, and perhaps at all times. Mr. R. E. Froude has pointed out in the passage already quoted that pitching tends to increase resistance; but there is, in addition, the further consideration that it practically limits speed in a heavy sea. The engines require to be slowed as soon as a ship pitches so as to take heavy water on board or to lift the propellers sufficiently out of the water to cause racing; and it is the ship that moves easily over the seas without requiring the engines to be slowed on account of pitching that makes the best passages in bad weather. Circumstances which thus influence, and often limit, speed at sea are not taken into account in still-water experiments; and I doubt if it would be possible to arrange to do so, in a way that would be satisfactory, in any experiments with models.

Deep Draught of Water.—This is a most important element of speed at sea, and it is now strictly limited by the depth of water in the ports and docks used by the fast passenger steamers on both sides of the Atlantic. Twenty-seven feet is the extreme limit of depth to which a ship can load on either side. The *Campania* cannot load an inch deeper than the *Umbria*, although she is 100 feet longer. If the underwater dimensions of *Campania* had been increased proportionately to those of *Umbria* her draught of water would have been 32½ feet. This class of steamers is increasing in length and breadth, but the draught of water has to be kept the same. The result is that it is only a question of time, and not of a very long time, with our present materials of construction and type of propulsive machinery, to find an absolute limit of speed imposed by the restriction of draught of water. The weight of steel in the hulls of this class of steamers varies almost as the cube of the linear dimensions in similar ships. This is a much greater ratio than is found in ships of smaller size, where thicknesses of material are often governed by considerations that are not directly related to the strength necessary to resist longitudinal straining at sea; but in these large ships, where the weight of much of the structural material is regulated mainly by the longitudinal strength required at sea,

it is not safe to allow much less than the variation of weight named. This practically agrees, subject to certain qualifications, with the conclusions arrived at by Mr. Froude in his paper on "Useful Displacement as Limited by Weight of Structure and of Propulsive Power," read before this Institution in 1874. Mr. Froude there showed that in similar ships of equal strength the weight of hull would vary as $\frac{\text{length}^4 \times \text{breadth}}{\text{depth}}$; and that, consequently, the weight of hull would vary as the fourth power of the length, whether the length only were increased, or all three dimensions were increased in the same ratio. This was based upon the assumption that the straining actions are those due to waves whose heights are proportional to their lengths. There is doubtless a small reduction due to the fact that the heights of sea waves do not increase quite in proportion to their lengths, and there is, besides, the important practical qualification that a large portion of the structural materials does not play a great part in resisting longitudinal straining action. The result of my own experience of some of the largest steamers is that in cases where the strength to resist longitudinal straining action at sea appears to be about the same, the weight of steel varies, or would vary if corrections for the want of exact similarlity were made, about in proportion to the cube of the linear dimensions.

What Mr. Froude really shows is that those portions of a ship's structure whose strength is relied upon for resisting longitudinal straining action at sea require to vary in weight as the fourth power of the dimensions under the conditions he states. Much of the structure of a ship, however, does not contribute materially to longitudinal strength, and does not require to be increased in weight, in the same ratio, with increase of dimensions. This, together with the reduction in amount of straining action due to diminution of the ratio of height to length of waves with size, must be taken to account for the fact that the variation of weight of structural materials found to be sufficient in practice is nearly as the cube instead of as the fourth power of the dimensions. With regard to the wood work, fittings, and equipment that go to complete the total weight of a ship's hull, their

weight does not, as a whole, vary at such a high rate even as the cube of the dimensions. If a ship's dimensions only are increased, all in the same ratio—keeping the same number and thickness of decks—much of the wood work, such as the wood decks and the work upon them, would only vary as the square of the dimensions. The final result is that in similar ships of the largest size the total weight of hull may be taken to vary as rather less than the cube of the dimensions. No doubt the rate of variation is kept down by the fact that, as ships are increased in size, the details of the structural arrangements and the riveted work are all carried out with greater care and efficiency, and with the result of obtaining more perfect continuity of strength, and consequently greater strength out of the same weight of materials.

While the weight of the whole hull varies approximately as the cube of the dimensions, the displacement can only vary as the square, in similar ships, so long as the draught of water is fixed. Hence, a point would ultimately be reached beyond which increase of displacement would be exceeded by the increase in weight of hull necessary for the requisite strength of structure, and beyond which speed would be limited by inability to carry any more engine power.*

It is not only that the present limited draught of water will finally impose an absolute limit of speed, other conditions remaining the same, but it has already a very prejudicial effect in keeping down speed at the point actually reached. If the draught were not restricted, the form of section could be improved by giving to it more rise of bilge and an easier curvature. The resistance could be reduced by giving the section such a form and proportions as would increase the draught of water. At the load draughts of the present ships the indicated horse power required for a given speed does not vary as the displacement with increase or diminution of draught of water. It often varies

* See "Note sur la Loi de la Variation du Poids de la Charpente des Navires avec les dimensions, et sur la limitation qui en résulte dans la grandeur absolue," by M. Augustin Normand, member of this Institution, and my own remarks on the same in the "Bulletin de l'Association Technique Maritime," No. 3, 1893.

as about the $\frac{2}{3}$ds power of the displacement. In some cases it may be as low as the square root. In other words, as the displacement is increased by increase of draught, the power required to drive a ton of displacement at a given speed becomes reduced. Hence, increase of draught does not mean a proportionate increase of engine power, even when such increase is obtained merely by extra immersion, without any improvement of form, such as would otherwise be possible.

The advantages of increased draught would be felt still more in a seaway than in smooth water, as the lower part of the hull would be less affected by the wave surface, and better and more constant immersion could be given to the propellers.

Steadiness in a Seaway.—Steadiness is important, not only as a very desirable element of comfort to passengers, but also as contributing to speed. When a vessel is rolling heavily from side to side her resistance must be increased. This is shown by the fact that whereas bilge keels have an appreciable effect upon speed on a smooth water trial, they cause no reduction in speed upon sea voyages—at any rate, that is my own experience. The advantages of bilge keels are well known in the Royal Navy, but they are not generally understond in the mercantile marine. They are often objected to on the ground of the increased frictional resistance they offer. This increase of resistance is, however, fully compensated for at sea by the reduction of resistance due to diminished rolling. The following is a typical case: I was consulted several years ago about the design of one of the largest and fastest passenger steamers, and recommended that she should be fitted with bilge keels. This was opposed by all who had to do with her, and they were not fitted. One of the managing owners informed me afterwards that the ship rolled very badly and asked my advice. I recommended him again to try bilge keels, and they were fitted for about one-third of the length of the ship, their depth being 2 feet 3 inches. She has now been running four years with the bilge keels, and the result is that she is reported not to roll more than one-half to the extent she did before, and not to show any difference that can be detected in speed or coal consumption. The success has been

so marked in this instance that the other ships of the line have since been similarly fitted.

It would add greatly to the comfort of passengers if rolling could be reduced in these large steamers, and bilge keels furnish a ready and certain way of doing it when they are properly fitted and are of appropriate size. The objection in some of the largest ships is that the docks they have to use do not admit of it. None of the fast Atlantic steamers are so fitted. Rolling chambers, containing water free to move from side to side, have been tried in some ships; but, I understand, they have sometimes failed in their action under the worst conditions of the heaviest rolling. The *New York* and *Paris* were fitted originally with rolling chambers, but I am not aware that they were ever used.

Strength of Structure and Machinery.—This is a matter of the greatest importance in all steamers that require to make quick passages in bad weather, as must be self-evident, and I need not say much upon it. A good margin of weight pays in the long run, both in hull and machinery, by reducing the amount necessary to be expended annually upon up-keep and repairs, and preventing the taking a costly vessel off her station and losing her earnings occasionally for the purpose of repairs. It also contributes materially to the maintenance of a high average speed by preventing temporary breakdown or stoppage of machinery at sea. It is a question, however, whether the limit of length has not now been reached with the present structural arrangements, and whether the promenade deck, shown in the *Campania's* section, Fig. 4, should not, as a next step, be made the structural upper deck of the ship. This would be approaching more nearly to the proportions of the *Great Eastern.* It would necessitate some modification of the arrangements under the present promenade deck; but this is a step which now appears to be called for, and it would certainly be necessary with any further increase of length to increase the depth of the main structure of the ship in this manner. If this be not done the vibration is likely to be excessive, especially when the revolutions of

the engines approach to synchronism with the period of vibration of the hull.

A Large Proportion of Boiler Power.—The necessity for this is also well known. The best results upon short trials are obtained with large engines and small boilers; but the best results at sea are obtained with smaller engines and large boilers. This is also an instance in which short trials fail as a standard of what can be done upon a long voyage at sea.

Twin screws are now becoming usual in the largest class of passenger steamers. They were a necessity in the latest Atlantic liners, if only because of the necessity of keeping down the size of the machinery by dividing it into two sets. The immunity thus given against total breakdown of the propelling machinery is now appreciated, and no single-screw ship is likely to be built again for the Atlantic passenger trade. The number of propellers is more likely to be increased in the future than diminished. The two engine rooms are usually divided by a middle line bulkhead; but it is necessary to have water-tight doors in this bulkhead to admit of free communication between the two engine rooms. In the event of accident these doors would be closed. The objection often made to a middle line bulkhead, that water upon one side would list the ship, is met by the arrangements for admitting water ballast upon one side of the double bottom, which would counteract any such list.

The improvements that would have the greatest effect in promoting the increase of speed at sea are: Increase of depth of water in harbors and docks, such as would admit of much greater draughts of water being obtained, and improvements in boilers, by which greater steam power could be developed out of the same space and weight. Mr. Milton is to read a paper upon Water-tube Boilers, a type of boiler to which many are looking with hope for the future. In the matter of boilers, however, it is necessary to move very cautiously, and, above all, to run no serious risks. Stronger qualities of steel may also be obtained; but the tensile strength of steel used is not a measure of its efficiency for all the purposes of a ship's structure. The present steel is 40 or 50 per cent. stronger than the iron that was for-

merly used; but it cannot be reduced in thickness so as to save more than 12 to 15 per cent. in weight. In any improved material that may be introduced, the rate of elongation with tension, or, speaking more generally, the relation of strain to stress, may be more important than the mere tensile strength, as a ship's hull requires to be very rigid, and to be practically free from movements due to stretching or compression of materials.

The Atlantic trade is increasing at such a rapid rate that larger and swifter ships are certain to be soon called for. The depth of water has lately been somewhat increased at Liverpool; but much deeper harbors and docks will be required if further great increases of speed at sea are to be obtained without excessive difficulty and cost.

I have taken out of this paper some remarks upon the very important questions of the internal subdivision of the hulls of the largest class of steamers, the precautions necessary to make it effective in an emergency, and the degree of safety that should thus be insured in the event of accident by collision or other cause of damage. With the news of the dreadful catastrophe to H.M.S. *Victoria* still ringing in our ears, and the circumstances connected with it not yet fully brought to light, I have considered it undesirable to attempt to deal with a section of the subject of the paper which cannot at present be thought of apart from its possible bearing upon this great national disaster. I would only add, in view of Sir Edward Harland's remarks, at the last spring meeting, upon the manner in which the Report of the Bulkhead Committee has been received by those for whose benefit it was framed, that when the design of the *Campania* was first referred to me I had the question of internal subdivision looked into and carefully compared with the recommendation of the Bulkhead Committee; and it was finally arranged so as to carry out those recommendations in the most complete manner, and to rather exceed the requirements laid down in the Report.

SOME EXPERIMENTS ON THE COMBINATION OF INDUCED DRAFT AND HOT AIR, APPLIED TO MARINE BOILERS FITTED WITH "SERVE" TUBES AND RETARDERS.

By J. D. Ellis, Esq., Managing Director Messrs. John Brown & Co., Limited, Sheffield.

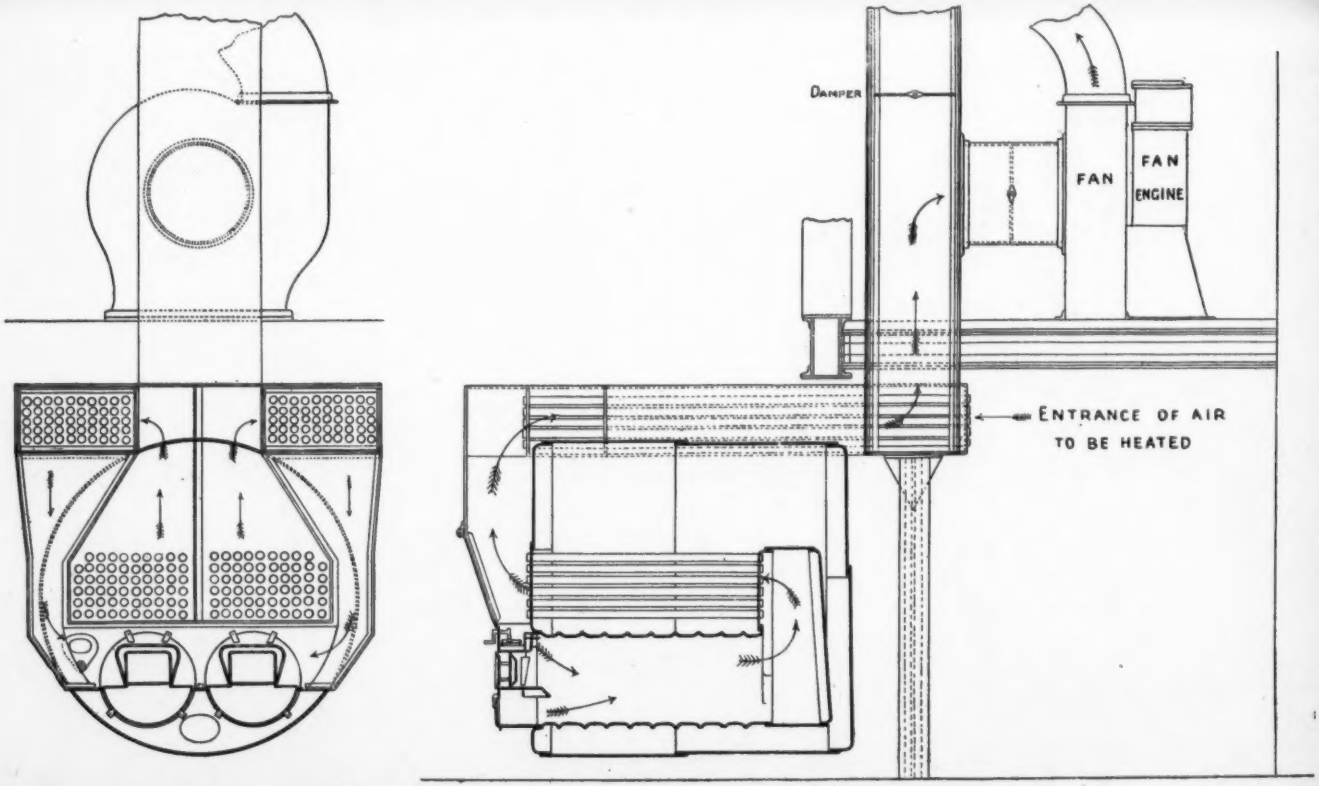
[Read at the Summer Meeting of the Thirty-fourth Session of the Institution of Naval Architects, July 12th, 1893.]

In these days of triple and quadruple-expansion engines and high speed for ships, I trust some remarks and results of experiments on the economical and efficient production of steam for marine boilers will not be uninteresting to the members of this Institution.

The combined use of strong artificial suction draft, "Serve" tubes, and retarders, and further utilizing the heat of the gases when they have left the boiler, seem to me the natural outcome of the requirements of the day.

The engine power demanded by the present ships has advanced by leaps and bounds, and two of the latest built have reached a power of over 30,000 I.H.P. each. It has, therefore, become an urgent necessity to obtain more work per cubic foot of boiler than hitherto, not only without loss, but, if possible, with a gain of economy.

The height of smoke stacks for natural draft has increased with the increase in the size of the ships, and thus a vacuum of about half an inch of water has been reached, being nearly twice as much as had been obtained only three or four years ago in the great majority of vessels with natural draft. In other vessels the draft has been artificially increased by blowing air into an open or closed stokehold or closed furnace. Mr. Martin has


DAMPER
FAN
FAN ENGINE
ENTRANCE OF AIR TO BE HEATED

worked in the direction of exhausting the gases by fans in the funnel, instead of forcing the air into the boilers. Jets of steam or compressed air in the funnel have been tried to obtain an increase of draft. Mr. Howden has, in addition to his forced draft, utilized some of the heat of the waste gases by heating the air, making it pass round a nest of short vertical tubes through which the waste gases go from the smoke box to the funnel. In other cases, the air has been heated slightly by the heat which would otherwise have been lost by radiation. Retarders have been used by Mr. Howden in plain tubes with forced draft to bring the swiftly-passing gases into better contact with the heat-absorbing surface, and have thereby, as well as to some extent by radiation, been a source of economy.

The advent of the "Serve" tubes has marked another important era in the history of boilers. The heat-absorbing surface of the "Serve" tube is much greater than that of a plain tube of the same ouside diameter, and a retarder placed in the center of the "Serve" tubes makes, for a draft of three-quarters of an inch and over of water pressure or vacuum, the most efficient and economical combination I know at present.

Having ascertained in ordinary single-ended Scotch marine boilers the value of the "Serve" tube and of the retarder with different rates of draft, with Martin's induced draft with cold air, and Howden's forced draft with heated air, it seemed to me that a considerable improvement was possible over existing practice by combining and extending the best features of the various systems, and the accompanying drawing, No. 1, shows this combination as it has been at work in boilers Nos. 7 and 8 for over twelve months at the Atlas Works.

I have preferred artificial suction draft to forced draft, because it seemed the natural way of increasing the efficiency, being natural draft intensified, produced by artificial means, merely because the equivalent height of smoke stack cannot be used at sea. Seeing that in any case, whether the draft be suction or forced, a given quantity of air must pass through the boiler at a certain speed to produce a given combustion, and being of opinion that suction draft was less likely to produce trouble in the

combustion chamber than forced draft at the high rate of combustion I had in view, the best means applicable at sea of obtaining this kind of draft had to be considered. Steam jets in the funnel could not be entertained, because of the loss of the water. Air jets were doubtful. Fans had been tried for exhausting the gases, and the heat had given trouble, even when burning at rates far below those intended by me, or, to avoid the gases passing into the fans at a high temperature, the tubes had to be made very small in diameter, therefore liable to choke readily, and reducing greatly the amount of coal which could be burnt with a given rate of draft compared with ordinary sized tubes. Besides this, the crowded tubes impeded circulation within the boiler. I knew the "Serve" tubes and retarders would reduce the heat of the gases appreciably within the boiler itself; but, as I desired to burn at the rate of 45 pounds to 60 pounds per square foot of full-size grate, therefore three or four times the rate of ordinary natural draft, the temperature of the gases escaping from the boiler into the smoke box would still be high, and required to be further absorbed for the double purpose of preventing difficulty with the fans and increasing the efficiency per pound of fuel. A nest of short, vertical air-heating tubes, as in the Howden system, would do good, but I desired something more, because I wished to burn at a higher rate. Thus I came to horizontal tubes, which are more effective than vertical ones, and which can be used of greater length. The ultimate combination and extension is shown in drawing No. 1, the leading features of the boiler being, therefore—

(1) Suction or induced draft.

(2) The utilization of the waste gases for heating the air before it passes into the furnace.

(3) "Serve" tubes.

(4) Retarders in the tubes.

The principal dimensions of the boilers are as follows:

Boiler:

Diameter of boilers, ...	10 ft. 6 in.
Length of boilers, ...	10 ft. 6 in.

Boiler:

"Purves" flues in each boiler,	2
Inside diameter of flue,	2 ft. 10½ in.
Length of furnaces,	7 ft. 6½ in.
Total number of tubes ("Serve"),	118
Outside diameter of tubes,	3¼ in.
Thickness of ordinary tubes,	0.116 in.
Number of stay tubes,	44
Thickness of stay tubes,	0.144 in.
Pitch of tubes from center to center,	4⅜ in.
Total heat-absorbing surface of tubes,	1,303.6 sq. ft.
Heat-distributing surface of tubes,	741 sq. ft.
Heat-distributing surface of furnaces,	75 sq. ft.
Heat-distributing surface of combustion chambers,	95 sq. ft.
Total heat-distributing surface per boiler,	911 sq. ft.
Area of grate surface,	32 sq. ft.
Length of grate,	5 ft. 8 in.
Bars, 3 in. deep, ¾ in. thick, and ⅝ in. air space.	
Proportion of grate to total heating surface,	1 to 28.4

Air-heating boxes:

In the heat-absorbing chambers there are,	80 tubes (plain).
Diameter of tubes outside,	3 in.
Length of tubes,	14 ft. 4 in.
Thickness of tubes,	0.116 in.
Total heat-absorbing surface,	900 sq. ft.

Fans and engines:

Fan to each boiler,	1
Diameter of fan over tips of blades,	5 ft. 6 in.
Width of fan,	1 ft. 9 in.
Diameter of engine cylinders (two cylinders)	7 in.
Stroke,	5 in.

It will be seen that the boiler itself is an ordinary single-ended Scotch-type marine boiler, with "Purves" furnaces and "Serve" tubes. The combustion chamber is fairly large for the

size of boiler. The tubes, 3¼ inches outside diameter, are spaced somewhat further apart than is customary now, and good circulation of water and ready escape of steam are thereby facilitated. In selecting so large a diameter of tubes—instead of the usual small diameters—for high rates of combustion, I was not concerned as to the amount of heat-"distributing" surface within the boiler, and this finally came out at the proportion of 28.4 square feet to one square foot of grate surface. Small plain tubes have been necessary previously for the sake of obtaining the utmost heat-absorbing surface; but by using the "Serve" type of tube, I obtained much more heat-absorbing surface with the smaller number of 3¼-inch tubes widely spaced, than could be done with a large number of small diameter plain tubes closely pitched. The advantages are obvious. Increased section for the passage of the gases; increased heat-absorbing surface, and better circulation of the water and escape of steam. Events have proved that in these boilers prolonged evaporation can take place, without trouble, and from cold feed, at unprecedented rates for this class of boiler.

The grate is in two lengths; the bars are ordinary wrought-iron bars, 2 feet 10 inches long by 3 inches deep, ⅜-inch thick at top by ¼-inch at bottom, spaced ⅝-inch apart. The only departure from ordinary practice is that the grate for high rates of combustion, say, over 35 pounds, rises towards the back (2 inches in 5 feet 8 inches total length), instead of falling about 2 inches as is usual. Up to 35 pounds per square foot the grate may be horizontal. I did not arrive at this conclusion without considerable experiment. At one time it seemed as if I should require to have recourse to a tubular grate with air or water passing through the same; but, realizing the objections to such grates, I persevered, after having repeatedly burnt down in half an hour a new wrought-iron grate composed of bars as above, sloping downwards. The gradual raising of the back end to 2 inches above front end has resulted in our being entirely relieved of all anxiety as to the grate, even when burning at 60 pounds per square foot.

For convenience of admission of the air in proper quantities

above or below the grate, I use the cast-iron mouthpieces introduced by Mr. Howden, and have modified them to my requirements. The Howden mouthpiece has one valve over the fire, and two at the side for the air to pass under the grate. I have added two valves over the fire, as I found the usual practice gave incomplete combustion with certain classes of coal, because it did not admit sufficient air over the grate. In our boilers the three top valves are wide open, and the two side valves shut, for smoky coal, and *vice versa* for non-smoky coal. A number of small holes in the bottom furnace doors allow a certain quantity of cold air to be drawn in under the grate, and it is only the heated air which is put sometimes over, sometimes under the grate, according to the nature of the coal. Thus we have found every sort of coal can be burnt with economy without smoke.

The accompanying tables of experiments give the results of various classes of coal, moderate and high rates of combustion, short and long trials, and grates cleaned at great and smaller intervals. These results, I trust, are individually and collectively interesting. I have endeavored to eliminate all circumstances which might make the results doubtful. For experiments, the water is taken from tanks made of cast-iron plates planed to template. The inside dimensions are 4 feet 5 inches by 4 feet $4\frac{1}{2}$ inches by 9 feet high. One inch depth of water equals ten gallons = 100 pounds. The quantity pumped into the boilers can be read off at any time by the scaled gauge glasses. The coal is weighed out carefully as the trials proceed. Mercury thermometers are used for temperatures to 600° F. Only one indication needs the means of measuring a higher temperature, viz: the smoke box. For this we now use metals of which the melting point is well known, in preference to any kind of pyrometers. The trials commence with the fires burnt down to a minimum, and finish, as near as possible, with the same height of fire and same condition. The tables show how the temperature of the gases is greatly reduced before they reach the fans, and the heat utilized by the high temperature of the air and the satisfactory evaporation per pound of coal.

Leaky tube ends are unknown, and coke nests have been found to occur only with coal from certain mines. The heat-distributing surfaces evidently do their work well, one square foot of heating surface having evaporated as much as 16.8 pounds of cold water (70°) per hour (see test No. 4) with Scotch coal for seven hours without cleaning the grate, averaging a combustion of 59.34 pounds per square foot of grate over the whole period.

In our experiments we have already used South Wales, Newcastle, South Yorkshire, Scotch, Lancashire, Pennsylvanian and Australian coal, and it is intended to continue the experiments until all the different kinds principally used in our mercantile navy have been tried and the comparative results ascertained.

I am well aware that these experiments have been made on land, and with a comparatively low pressure of steam, but I am unable to see any sufficient reason why similar advantages and results should not be obtained at sea, if the system be adopted, provided care is taken to keep the boilers reasonably free from oil and solid matter. One ship thus fitted is working satisfactorily, and several others will be running shortly.

Besides the principal advantages of high evaporation with economy and safety, thereby reducing the number of boilers (consequently the boiler space and weight hitherto required), the following further advantages appear to me not unimportant:

Cool stokehold or engine room, if the air supply is taken from the latter instead of the atmosphere.

Clean stokehold, the coal dust being sucked into the boilers.

Absence of risk of burns to firemen, the flame at all times being sucked away from them.

Convenience to firemen, there being no valves to shut or open, when opening or closing the doors.

Smoke with unskillful firing is greatly reduced, and with careful firing need not occur at all, with any kind of coal.

Great elasticity of power under ready control.

Greatly reduced quantity of clinker and residue.

In making these results of the combination public, I desire to express my indebtedness to the eminent French engineer, Mr. J. Serve, for his valuable suggestions, and to the staff at the Atlas Works.

TABLE I.

RESULTS OF EXPERIMENTS MADE WITH "SERVE" TUBES AND INDUCED HOT-AIR FEED ON AUGTST 23 TO 27, 29 TO 30, SEPTEMBER 1 TO 2, 2 TO 3, 1892, ATLAS WORKS, SHEFFIELD.

NOS. 7 AND 8 MARINE BOILERS. "SERVE" TUBES WITH RETARDERS AND INDUCED HOT-AIR FEED.

Date.	Duration of trial, in hours.	Total coal burnt, in pounds.	Coal burnt per hour, in pounds. (Yorkshire.)	Total water evaporated, in pounds.	Water evaporated, per hour, in pounds.	Pounds of water per pound of coal evaporated at actual temperature of feed.	Pounds of water evaporated per pound of coal, from and at 212°.	Pounds of coal burnt per square foot of grate per hour.	Temperature of air at side valves, Fahrenheit.	Temperature of gases at base of chimney, Fahrenheit.	Temperature of gases in smoke box, Fahrenheit.	Vacuum under grate bars.	Vacuum over fires.	Vacuum at base of chimney, in inches, of water.	Vacuum above outlet of fan.	Speed of air under grate bars, in feet, per minute.	Average temperature of feed water.	Average steam-boiler pressure per square inch.	Revolutions of fan and engine per minute.	Air spaces in grate.	Thickness of bars.	Pounds of water per square foot of heat-distributing surface per hour.
1892.									*deg.*	*deg.*	*deg.*	*in.*	*in.*	*in.*		*ft.*	*deg.*	*lbs.*		*in.*	*in.*	
Aug. 23 to 27..	96	123,648	1,288	1,102,800	11,487.5	8.91	10.29	40.25	263	393	656	...	.48	4.68	...	1,207	87	44	541	⅝	¾	12.6
Aug. 29 to 30..	24	34,552	1,439.6	303,700	12,654.1	8.78	10.24	44.98	305	386	653	...	.39	3.37	...	1,451	76	46	463	⅝	¾	13 89
Sept. 1 to 2....	24	32,805	1,366.8	295,500	12,312.5	9.00	10.45	42.71	262	386	618	.77	1.16	4.56	...	...	81	45	525	⅝	¾	13.51
Sept. 2 to 3....	24	32,928	1,372	297,000	12,375	9.10	10.48	42.87	294	391	692	.65	.72	5.05	...	...	79	45	571	⅝	¾	13.58

AUGUST 23 TO 27.—In this experiment all bars were cleaned and tubes swept before starting; fires were cleaned every twelve hours alternately; the tubes were not swept during the whole of this trial. In this test all hot air was passed above the fires, and cold air underneath, the bottom doors being half open to allow admittance of cold air.

AUGUST 29 TO 30.—In this experiment new fire bars were put in, and tubes swept before starting; fires were cleaned every four hours; the tubes were not swept during the whole of this trial. In this test all hot air was passed above the fires, and cold air underneath, the bottom doors being half open to allow admittance of cold air.

SEPTEMBER 1 TO 2.—In this experiment all bars were cleaned and tubes swept before starting; fires were cleaned every six hours; the tubes were not swept during the whole of this trial. In this test the hot-air feed was both top and bottom, but underneath the bars the hot air was diluted with cold air, being admitted through seventy holes in each ashpit door; there was also a second perforated plate behind the ashpit door, for the purpose of mixing the air thoroughly. The temperature of air under grate was an average of about 150° Fahrenheit.

SEPTEMBER 2 TO 3.—In this experiment all bars were cleaned and tubes swept before starting; fires cleaned every six hours; the tubes were not swept during the whole of this trial. In this test all hot air was passed above the fires, and cold air underneath; the bottom doors being shut, the cold air passed through seventy holes drilled in each door for the purpose; area of these holes, 124 square inches, *i. e.*, 62 square inches in each door; area for passage of air over both fires, 220 square inches.

TABLE II.

RESULTS OF EXPERIMENTS MADE WITH "SERVE" TUBES AND INDUCED HOT-AIR FEED ON AUGUST 15 AND NOVEMBER 5, 8, 15, 17 AND 18, 1892, ATLAS WORKS, SHEFFIELD.

Nos. 7 and 8 Marine Boilers. "Serve" Tubes with Retarders and Induced Hot-Air Feed.

Date.	Duration of trial, in hours.	Total coal burnt, in pounds.	Coal burnt per hour, in pounds. (*American. †Nixon's Navigation.)	Total water evaporated, in pounds.	Water evaporated per hour, in pounds.	Pounds of water evaporated per pound of coal at actual temperature of feed.	Pounds of water evaporated per pound of coal, from and at 212°.	Pounds of coal burnt per square foot of grate bar per hour.	Temperature of air at side valves, Fahrenheit.	Temperature of gases at base of chimney, Fahrenheit.	Vacuum under grate bars.	Vacuum over fires.	Vacuum at base of chimney, in inches, of water.	Vacuum above outlet of fan.	Speed of air under grate bars, in feet, per minute.	Speed of air through heating tubes, in feet, per minute.	Temperature of air entering heating tubes, Fahrenheit.	Average temperature of feed water, Fahrenheit.	Average steam-boiler pressure in pounds per square inch.	Revolutions of fan and engine per minute.	Thickness of grate bars.	Pounds of water per square foot of heat distributing surface per hour.
1892.									*deg.*	*deg.*	*in.*	*in.*	*in.*	*in.*		*ft.*	*deg.*	*deg.*			*in.*	
Nov. 5.....	4	4,969	1,242.25*	47,550	11,887.5	9.56	11.28	38.82	307	380‡	...	.5	4.08	.25	1,902	486	85	65	49	505	3/4‖	13.04
Nov. 15...	7½	8,018	1,069.06*	72,500	9,666.66	9.04	10.63	33.4	246	331‡	.88	1.2	4.35	.36	2,176	1,249	66	66	45	498	1/2¶	10.61
Nov. 17...	5	5,632	1,126.4*	52,600	10,520	9.33	11.02	35.2	246	336‡	.91	1.27	4.37	.35	2,404	1,220	51	59	43	490	1/2¶	11.54
Aug. 15...	7	7,443	1,063.28†	68,900	9,842 85	9.25	10.83	33.22	200	290ƨ	1.07	1.64	2.65	...	...	....	....	72	45	382	3/4ε	10.8
Nov. 8.....	48	67,268	1,401.41†	599,700	12,493.75	8.91	10.5	43 79	311	442ƨ	...	.62	6.13	.33	1,319	508	64	66	49	634	3/4ε	13.71
Nov. 18...	7	10,192	1,456†	99,300	14,185.71	9.74	11.44	45.5	265	374ƨ	.78	1.3	4 87	.36	2,658	1,141	57	67	45	548	1/2¶	15.57

‡ Lead was melted in the smoke box. ƨ Zinc was melted in the smoke box. ε Temperature in the smoke box 442°. ‖ Air spaces of grate bars—Front 5/8 inch; back, 1/4 inch; ¶ 1/2 inch; ε 5/8 inch.

Remarks.—In these experiments with Welsh and American coal, the best results were obtained by putting all the hot air under the grate with the ashpit doors closed, the hot air being diluted by the cold air being admitted through the holes in ashpit doors. Fires kept a moderate thickness. During the forty-eight hours' test the mode of admitting the air was tried in various ways, but the best results were obtained as above stated. This experimenting with the valves accounts for the apparently low evaporation. The fire bars in this test were partly cleaned every eight hours; but in the others they were not cleaned during the whole of the tests. Melting point of lead 630 degrees Fahrenheit, of zinc 700 degrees Fahrenheit.

TABLE III.

RESULTS OF EXPERIMENTS MADE WITH "SERVE" TUBES AND INDUCED HOT-AIR FEED ON FEBRUARY 24, 27, AND MARCH 15, 1893, ATLAS WORKS, SHEFFIELD.

No. 7 Marine Boiler. "Serve" Tubes with Retarders and Induced Hot-Air Feed.

Date.	Duration of trial, in hours.	Total coal burnt, in pounds.	Coal burnt per hour, in lbs. (Newcastle.)	Total water evaporated, in pounds.	Water evaporated per hour, in pounds.	Pounds of water evaporated per pound of coal at actual temperature of feed water	Pounds of water evaporated per pound of coal, from and at 212°.	Pounds of coal burnt per sq. foot of grate bar per hour.	Temperature of air at side valves, Fahrenheit.	Temperature of gases at base of chimney, Fahrenheit.	Vacuum under grate bars.	Vacuum over fires.	Vacuum at base of chimney, in inches, of water.	Vacuum above outlet of fan.	Speed of air under grate bars, in feet, per minute.	Speed of air through heating tubes, in feet, per minute.	Temperature of air entering heating tubes, Fahrenheit.	Average temperature of feed water, Fahrenheit.	Average steam-boiler pressure, in pounds per square inch.	Revolutions of fan and engine.	Grate bars.		Pounds of water per square foot of heat-distributing surface, per hour.
																					Air space.	Thickness of bars.	
1893.									*deg.*	*deg.*	*in.*	*in.*	*in.*	*in.*			*deg.*	*deg.*			*in.*	*in.*	
Feb. 24...	7	9,632	1,376	88,100	12,585.71	9.14	10.81	43	279	408*	1.01	1.17	5.06	.375	2,464	1,167	61	61	47	573	⅝	¾	13.81
" 27...	7	10,304	1,472	96,600	13,800	9.37	11.18	46	281	392*	.93	1.24	4.62	.375	2,098	1,332	61	50	47	510	⅝	¾	15.14
Mar. 15..	7	10,192	1,456	92,300	13,185.71	9.05	10 66	45.5	276	390†	1.25	1.57	5.42	.375	2,586	1,570	65	66	49	567	⅝	¾	14.47

* Bismuth was melted in smokebox. † Lead was melted in smokebox.

Remarks.—February 24: In this experiment all the hot air was passed above the fires, and cold air underneath, the bottom doors being shut, the cold air passed through 70 holes drilled in each door for the purpose. February 27th and March 15th: In these experiments all the hot air was passed under the fires, but was diluted with cold air, admitted through 70 holes in each ashpit door. In the above experiments the fire bars were cleaned and tubes swept before starting. The fire bars were not cleaned again during the whole of the 7 hours' test. Melting point of bismuth, 493 degrees Fahrenheit; of lead, 630 degrees Fahrenheit.

TABLE IV.

RESULTS OF EXPERIMENTS MADE WITH "SERVE" TUBES AND INDUCED HOT-AIR FEED, MAY 5 AND 8, 1893, ATLAS WORKS, SHEFFIELD.

No. 7 Marine Boiler. "Serve" Tubes with Retarders and Induced Hot-Air Feed.

Date.	Duration of trial, in hours.	Total coal burnt, in pounds.	Coal burnt per hour, in pounds (Scotch).	Total water evaporated, in pounds.	Water evaporated per hour, in pounds.	Pounds of water evaporated per pound of coal at actual temperature of feed.	Pounds of water evaporated per pound of coal, from and at 212°.	Pounds of coal burnt per sq. foot of grate bar per hour.	Temperature of air at side valves, Fahrenheit.	Temperature of gases at base of chimney, Fahrenheit.	Vacuum under grate bars.	Vacuum over fire.	Vacuum at base of chimney, in inches of water.	Vacuum above outlet of fan.	Speed of air under grate bars, in feet per minute.	Speed of air through heating tubes, in feet per minute.	Temperature of air entering heating tubes, Fahrenheit.	Average temperature of feed water, Fahrenheit.	Average steam-boiler pressure, in pounds per square inch.	Revolutions of fan and engine per minute.	Grate bars.		Pounds of water per square foot of heat-distributing surface per hour.
																					Air space.	Thickness of bars.	
1893.									*deg.*	*deg.*	*in.*	*in.*	*in.*	*in.*			*deg.*	*deg.*			*in*	*in.*	
May 5...	7	11,228	1,604	91,600	13,085.71	8.15	9.46	50.12	300	416*	.99	1.22	4.58	.375	2,445	1,150	83	82	46.6	542	5/8	9/16	14.36
May 8...	7	13,293	1,899	107,200	15,314.2	8.06	9.45	59.34	293	434*	.93	1.26	4.58	.375	1,981	1,448	83	70	46	544	5/8	8/16	16.81

* Lead was melted in smoke box.

Remarks.—May 5, 1893: In the 7 hours' run the fires were not cleaned for the whole of the 7 hours. The fires were kept very thick and all the hot air put on top of fire, the cold air only being admitted under grate. May 8, 1893: In this test of Scotch coal, the bars were again not cleaned during the whole of the run, but the fires were very thin, and the whole of the air, both heated and cold, was passed under the grate. The results were, it will be seen, much better even than on May 5. Melting point of lead, 630 degrees Fahrenheit.

DISCUSSION.

[Reprinted from "Engineering."]

Mr. Fothergill, of Hartlepool, was the first speaker. He said that his own experience showed that the greatest difficulty in the use of forced draft arose from the firemen. Mechanical draft, with the closed ashpit, wanted regular firing, and they could not get men to attend to this point. The stokers said the job was not worth having unless they could heap on coal by the barrow-load. With forced draft the fuel should be spread evenly and regularly over the grate. He questioned the value of heating the air supplied to the furnace. He admitted that each unit of heat returned was a unit gained, but it was nothing more. By the tables appended to the author's paper, the speaker noticed that the temperature of the gases in the smoke box was 611 degrees Fahrenheit, whilst the temperature of gases at the base of the chimney was 392 degrees Fahrenheit. The total heat absorbed could not, therefore, amount to more than 219 degrees. This was the utmost for which credit could be claimed, even supposing the apparatus were absolutely perfect. That would not take into account any loss from radiation, or from other causes, which must largely influence the result. The specific heat of air, the speaker pointed out, was low, and passing through the tubes as it did, he questioned if much heat was absorbed. In making these remarks, Mr. Fothergill had accepted the records given as absolutely correct; and, no doubt, they were, as far as the author of the paper and those associated with him could make them so; but there was great difficulty, Mr. Fothergill pointed out, in obtaining trustworthy records in such cases. He had, himself, experienced the manner in which investigators could be led astray in endeavoring to take temperatures by thermometers in similar cases, more especially in regard to the way in which the records of the thermometer were affected by radiation from adjacent heated bodies. In the boilers referred to in the paper the tube area was small, and the probability was that the heat was not absorbed by the water in the boiler through the

tubes. He questioned if there was any advantage in letting the heat escape and catching it afterwards.

Mr. Fothergill next quoted the details of some experiments made by Mr. F. C. Marshall, of Newcastle, in support of his statement, and he came to the conclusion that, in regard to the apparatus described by the author in his paper, it was questionable whether the game was worth the candle. He thought it would be better to trap the heat of the escaping gases by warming up the feed water; more especially as the specific heat of water was more than four times that of air. There was another way of looking at the matter. If the temperature of the air were increased 450 degrees, its volume would be doubled, and, therefore, an exhaust fan for inducing the draft of double the size and power would be required. This fact appeared to be borne out by the particulars in the paper. He could, however, congratulate Mr. Ellis on burning 50 pounds of coal per square foot of grate per hour without damaging the grate. He (the speaker) had burnt 40 pounds per square foot of grate per hour, evaporating 10.4 pounds of water per pound of coal, from and at 212 degrees Fahrenheit. That was a very satisfactory result. In the trial of the *Iona*, made by the Research Committee of the Institution of Mechanical Engineers, with cold air and no Serve tubes, they had evaporated 10.63 pounds of water per pound of coal, but the rate of combustion was less in terms of the grate area, and there was also greater heating surface in terms of the combustion. The author had referred to heat-absorbing surface of the tubes, and to heat-distributing surface. These terms, the speaker thought, were new. With regard to the Serve tubes generally, he believed they would afford economy. There were practical difficulties in the way of using them, but these would be overcome. The trials quoted by the author were undoubtedly interesting, but they were carried out under conditions very different to those which would apply at sea. Mr. Fothergill would like to have seen a steamer fitted up and run for twelve months, having plain tubes. She should then be retubed with Serve tubes, other conditions being similar, and the experiment should then be carried on for another twelve months.

Analyses of gases should be made. These were not given in the paper, but they were a most important feature in marine-engine trials, as by them the quantity of air supplied was known. Anemometers were of no value for measuring air under such conditions.

Mr. F. Milton was the next speaker. He would bear testimony to the accuracy of the results quoted by the author. No pains had been spared in order to accurately record the results observed during these trials. In regard to the bearing of the paper, the whole question involved was one of economy to be obtained. It would be observed that Mr. Ellis had really adopted what was in effect a compound boiler. He had first of all an ordinary boiler with a given area of heating surface, and had supplemented this by an apparatus to get the waste heat out of the gases. He thought, however, that the good results quoted in the paper were chiefly due to the more perfect combustion of the coal. The author admitted the heated air above the fire, and that, Mr. Milton thought, fully accounted for any advantage shown over the working of a boiler in the ordinary manner, where the air was all taken in below the furnace bars. The second stage of the apparatus was really the regenerative boiler, and the absence of cold air to supply the furnace would doubtless allow the gases set free by the distillation of the coal to enter into combustion in a manner which would not take place if air of ordinary temperature were used.

Dr. White, the Director of Naval Construction, and Assistant Controller, regretted that illness prevented the Engineer-in-Chief to the Royal Navy, Mr. Durston, from being present to speak on this paper; in his absence the speaker would venture to make a few remarks on a subject which did not come in its details within his province. He had, however, seen the apparatus, and was much struck with the perfection of the experiments, and the care taken to get true results. He had asked Mr. Ellis to write a paper on the subject for the present meeting, but the author was unwilling to do so, his modesty restraining

him; and it was only with some difficulty that Dr. White persuaded him to take the step.

Turning to the details of the paper, the speaker pointed out that the conditions of trial were more favorable than on board ship. The supply of air to the furnace was open and unrestricted, so that the work of the fans was very easy compared to that which would be the case on board ship. The fact was admitted by the author, and the experiments were confessedly only put forward for comparative purposes, but in reading the tables this must be remembered, and the comparison must not be made with absolute ship trials, where these favorable conditions were not present. There had been, however, experiments made on shipboard, and he would ask Mr. Ellis to give particulars of what had been done. He thought in such cases the power required to work the fans would be appreciably higher. The Admiralty had made extensive trials with induced draft. These had been carried out on a locomotive boiler, and more recently on a torpedo gunboat, in which one stokehold had been worked with closed draft, with closed hatches, in the ordinary way, and one with induced draft. The details of this experiment had not been worked out at present, but it did not appear that such advantages as Mr. Ellis' tables showed were to be obtained by the use of induced draft, as compared with forced draft. The induced draft was, however, cleaner, and there was the advantage of the stokehold being open. With regard to "bird's-nesting"—which we may explain for the benefit of those unacquainted with the term is an accumulation of an annulus of ashes on the tubeplate, around the entrance of each tube—Dr. White said there did not appear to be the advantage in the use of induced draft, as compared to forced draft, which had been anticipated. Induced draft was, of course, no new thing, and had been tried in many ways before. In the French service they had used it by means of air jets, placed in the funnel; but it had been set aside after a time, and the closed stokehold substituted for it.

Mr. S. H. Terry regretted that Mr. Ellis had not given the volume of air passing through the furnace, so that information

might be obtained as to the quantity used per pound of coal burnt. The omission was doubtless due to the difficulty of measuring air currents. The point of great importance in trials of this nature was to ascertain the volume of air passing to the chimney. Every additional foot of air supplied to the furnace over that necessary, carried away heat without doing a corresponding good amount of work. With regard to the induced draft system, he would point out that if the fan were put in the funnel, where it had to deal with the products of combustion and escaping gases, it would have a larger volume to act upon than in the case of dealing with cold air only. There was, however, more than this in the fact, for the fan acted on the principle of centrifugal force, so that the factor of weight was an important one. If the air were doubled in volume, its specific gravity would be decreased, and the circumstance would have an important bearing on the working. The point was one of considerable importance, especially on shipboard, where weight and space were necessarily confined by the limits of the situation.

Mr. R. R. Bevis, of Birkenhead, questioned whether it would not be better to use the extra weight involved by the arrangement described by the author in the more ordinary way, namely, by enlarging the boiler and retaining the usual design.

Mr. Gross, who had been connected with the author in his experiments, said that Mr. Fothergill had spoken as one might expect from the fact that he had not seen the boilers; if he had, he would not have made many of the remarks that occurred in his speech. The apparatus, as described, had been at work at sea in one ship, and the results obtained closely approximated to those given by the author. With regard to Mr. Bevis' remarks, he thought, on the figures given in the paper, that the extra cost involved in the fitting of the apparatus was more than paid for. It appeared to him that the speaker had not sufficiently taken into consideration the economy which they had obtained. A remark had been made as to the difference between heat-absorbing and heat-distributing surfaces, but the former might be taken

as the true factor in calculations, for they found by experience that if they could get the heat into the metal of the tubes it would be sure to be taken up by the water. In fact, if they could get a large area of heat-absorbing surface, the heat-distributing surface would take care of itself, provided always that it was clean. The late Dr. Kirk had reported on the system, and he had said that at the Atlas Works the same results had been obtained as in those recorded in the case of the *Iona's* trials, although but half the amount of coal was burnt per square foot of heating surface in the latter case, as compared to that consumed at the Atlas Works. That was taking the heat distributing-surface to calculate from in the case of the Serve tubes. It might be objected that this was not a fair comparison, but the speaker would point out that the additional surface acquired by the use of the ribs in the Serve tubes did not involve the same addition to weight as would be the case if the heating surface were enlarged in the more ordinary way.

Reference had been made by one speaker to the area through the tubes being small, but he preferred the use of fewer tubes, putting them farther apart, so as not to check the natural convection of the water when heated. In spite of the fewer tubes, however, they obtained more area than was absolutely needed.

With regard to what Dr. White had said on the air supply to the stokehold, and the effect of tortuous passages in checking the draft, he could say that they had had one ship running on the Atlantic since March 1, in which the system was fitted, and it was said that her stokehold was the coldest on the Atlantic. (Dr. White explained that he did not question the possibility of obtaining a sufficient volume of air with this system; the ques- which arose was the power that would be required for the purpose.) Mr. Gross, resuming, said that Dr. White had pointed out that with induced draft there was the same liability to those causes which induced leaky tube ends, but he had come to the conclusion that the Serve tube itself was a preventive to leaky tubes; the extra stiffness afforded by the ribs in the tube giving a more secure joint at the tube plate. Experience of locomotives on American railways supported this view, and they found

that there were no leaky tubes with the Serve tube; whilst with plain tubes they were troubled with this cause when working under similar conditions. His own opinion was that the stiffness afforded by the ribs prevented the tubes from shaking loose.

Mr. Ellis, in replying to the discussion, said that Mr. Gross had dealt very fully with most of the points raised, and there was, therefore, little for him to say. The vessel referred to as being fitted with the system described in the paper was the Inman liner *Berlin*. She was an old vessel, not well suited to their purpose, and therefore they did not get such good results as if the experiment had been made on a new ship. However, she certainly had done very much better than before. Other vessels were being built which could be fitted, and when they were tried valuable information would be obtained, which he should be happy to place before the Institution at some future time.

THE CONTRACT TRIALS OF THE U. S. GUNBOATS *MACHIAS* AND *CASTINE*.

By Passed Assistant Engineer J. K. Barton, U. S. Navy, and Passed Assistant Engineer R. G. Denig, U. S. Navy.

The steel, twin screws gunboats *Machias* and *Castine* were built by the Bath Iron Works, Bath, Maine, from designs furnished by the Navy Department; the contract price for the construction of each being $318,500. The steel plates were furnished by the Linden Steel Co., and the shapes by Carnegie, Phipps & Co., of Pittsburgh, Pa.

The two vessels are alike in every respect and each has a poop and a forecastle deck, with an open gun deck between, an athwartship bridge, and a longitudinal bridge connecting the poop and forecastle. A light water-tight deck extends from the stem to frame No. 81; the flat top is $\frac{5}{16}$ inch thick and rises 15 inches above and parallel to the load water line. The inclined sides are $\frac{3}{8}$ of an inch thick and extend 3 feet below and parallel to the load water line. A coffer dam for cellulose extends from frame No. 34 to No. 63, and the remaining triangular space between the water tight and protective decks is utilized for air ducts.

There are 98 frames in the hull, two feet apart, and three longitudinals on each side of the vertical keel. The thickness of the skin plating and inner keel plate is $\frac{11}{32}$ of an inch, and that of the outer keel plate $\frac{3}{8}$ of an inch. Two bilge keels extend from frame No. 25 to frame No. 71; are 92 feet long, 16 inches deep at frame No. 48 and taper to nothing at the ends. The point of the ram bow is 3 feet below the load water line and extends 3 feet forward of the top of the stem. There is no double bottom, and the water tight subdivision of the hull is similar to that of the larger ships. There are two trimming tanks, one

situated in the bow and the other in the stern. The forward trimming tank extends from frame No. 10, forward to the stem, and from the keel to the underside of the water-tight deck, and the after trimming tank from frame No. 85, aft, extending from the keel to the underside of the platform deck. The volume of the forward trimming tank is 379 cubic feet, giving a capacity of 10.82 tons of water, while the after tank has a volume and capacity of 424 cubic feet and 12.10 tons, respectively. These tanks are fitted with sluice valves and necessary connections draining to the main suction pipes of the drainage system, and also with flood cocks for filling from the sea.

The rig is that of a schooner without bowsprit, and the total sail area is 6,083.38 square feet.

There are seven boats—a steam cutter, sailing launch, two cutters, whale boat, whale boat gig and dinghy—and with the exception of the quarter boats, all are stowed inboard on skid beams.

The main battery consists of eight 4-inch rapid-fire rifles; one pivoted on the top-gallant forecastle, one on the poop and the remainder mounted on projecting sponsons on each side of the gun deck. The secondary battery consists of four 6-pounders; two directly in the eyes of the ship under the top-gallant forecastle, and the others on the poop deck over the after sponsons; also two 1-pounders, in the after cabin, with a direct fire aft. In addition to the preceding there will probably be two Gatling guns placed at the ends of the athwartship bridge.

Both vessels were built to be armed with the Howell torpedo, and each is fitted with a torpedo tube through the stem, discharging above the water line. The sponsons of the *Castine* are armored with 2¼-inch steel plate, each weighing slightly over 6,000 pounds, in this respect differing from the *Machias*, whose plates are of thin steel about ¼ of an inch thick, the steel makers not having been able to deliver the thicker plates in time.

The contract required an average speed of 13 knots for four consecutive hours, subject to a penalty of $5,000 for each quarter knot below, and a premium of $5,000 for each quarter knot above the contract speed.

HULL.

Material	Mild steel.
Where built	Bath Iron Works, Bath, Maine.
When built	1890–1893.
Length between perpendiculars, feet	190–0
Length, extreme, feet and inches	198–4
Beam, extreme, feet	32–0
Beam at L.W.L., feet	32–0
Ratio length (B.P.) to beam	5.94
Draught (moulded) forward for L.W.L., feet and inches	11–3¾
Draught (moulded) aft for L.W.L., feet and inches	12–9¾
Draught (moulded) mean for L.W.L., feet and inches	12–0¾
Displacement at load draught, tons	1,067.5
Displacement, per inch, at load draught, tons	10.18
Area of immersed midship section, square feet	324.64
Area of L.W.L. plane, square feet	4,207.61
Center of gravity of L.W.L. plane, aft of midship section, (frame No. 48), feet	3.70
Transverse metacenter above center of gravity, feet	2.15
Longitudinal metacenter above center of gravity, feet	192.75
Co-efficient of fineness on extreme dimensions	0.504
Co-efficient of fineness on midship section	0.854
Co-efficient of fineness of L.W.L.	0.692
Wetted surface (by girths), square feet	6,816.
Moment to alter trim one inch, foot tons	88.85

MACHINERY.

There are two main engines, of the Navy Department's design, vertical, inverted, direct-acting, triple-expansion. The high-pressure cylinder is forward, the intermediate next, and the low pressure aft. The cranks are placed at angles of 120 degrees, and for ahead motion follow in the order, H.P., I.P., L.P. Both engines are in the same water-tight compartment; the boilers are in the compartment immediately forward of the engines, and are fired from the after end.

All the cylinders are unjacketed, and each piston has one piston rod, with a crosshead working on a bar guide. The framing of the engines consists of wrought-steel columns, trussed by wrought-steel stays. The engine bed plates consist each of three steel castings bolted together and supported on wrought-steel keelson plates, built in the vessel. The crank shafts are made in three interchangeable sections and all shafting is hollow.

The shafts, piston rods, connecting rods and working parts generally, are forged of mild open-hearth steel.

The main valves are of the piston type for the high-pressure and intermediate pressure cylinders, and a double-ported slide for the low pressure, all worked by the Stephenson link motion, with double bar links. There is one piston valve for the high and two for the intermediate-pressure cylinders, the latter having a valve stem crosshead, and the piston valves, valve liners and valve gear are interchangeable. Starting valves are fitted to all cylinders, with suitable handling gear operated from the working platform. The reversing gear for each engine consists of a steam cylinder, 7 inches × 9 inches stroke, and a hydraulic controlling cylinder, 3½ inches diameter, placed vertically, and acting directly on an arm fixed on the reversing shaft. The gear is placed on the outboard side of the engine, between the intermediate and low-pressure cylinders, and secured to the bed plate, while the handling lever is on the working platform. By means of the usual sliding block in a slot on the reversing arms, the cut off can be varied between the following points: H.P. from .63 to .82; I.P. from .63 to .82; L.P. from .6 to .8, of the stroke.

The bearing faces of crossheads, eccentrics, main bearings and crank-pin brasses are lined with white metal, and metallic packing is used for the piston and valve rods.

The pistons are fitted with single packing rings, cut and tongued, the low-pressure ring having spiral springs to assist in setting it out.

There is a condenser common to both engines, cylindrical and of composition. There are two vertical, single-acting air pumps worked by overhead simple engines, and a circulating pump (centrifugal), operated by a vertical double engine. The auxiliary condenser is cylindrical, placed on the port side of engine room and fitted with a combined air and circulating pump.

Two marine locomotive boilers, as designed by the Bath Iron Works, in order to obtain increased grate and heating surface, were submitted to and approved by the Bureau of Steam Engineering, and were substituted in the place of the straightway

fire tubular boilers originally designed for these vessels. The forced draft is on the closed fire room system.

The following are some of the principal dimensions and ratios of the cylinders:

Cylinders, number for each engine	3			
Cylinders, diameter as finished	*Machias.*		*Castine.*	
	Starboard.	Port.	Starboard.	Port.
High pressure, inches	15 3/4	15 3/4	15 7/8	15 7/8
Intermediate pressure, inches	22 1/2	22 9/16	22 19/32	22 17/32
Low pressure, inches	35 1/8	35 3/32	35 7/32	35 5/32
Stroke of pistons, inches	24			
Valves, diameter of high pressure, inches	7 1/2			
Valves, diameter of I.P. (2), inches	7 1/2			
Valves, diameter of L.P. balance piston, inches	6			
Valves, effective area of L.P. balance piston, square inches	27.92			
Valves, Length of L.P., inches	25 1/4			
Valves, width of L.P., inches	35			
Area H.P. steam ports, maximum opening, square inches	Top 19.56			
	Bottom 21.40			
Area H.P. exhaust ports, maximum opening, square inches	Top 34.23			
	Bottom 29.34			
Area I.P. steam ports, maximum opening, square inches	Top 39 80			
	Bottom 42.78			
Area I.P. exhaust ports, maximum opening, square inches	Top 68.46			
	Bottom 58.68			
Area L.P. steam ports, maximum opening, square inches	Top 46.86			
	Bottom 64.22			
Area L.P. exhaust ports, maximum opening, square inches	Top 92.94			
	Bottom 91.70			
Valve stems, H.P. and I.P., diameter, inches	1 1/2			
Valve stems, H.P. and I.P., diameter through valve, inches	1 1/8			
Valve stems, L.P., diameter, inches	1 7/8			
Valve stems, L.P., diameter through valve, inches	1 1/2			
Main steam pipes (6 inches diameter), area of cross-section, square inches	28.27			
Exhaust pipe, I.P. (6 1/2 inches diameter), area of cross section, square inches	33.18			
Exhaust pipe, L.P. (8 1/2 inches diameter), area of cross section, square inches	56.74			
Exhaust pipe to condenser (11 inches diameter) area of cross section, square inches	95.03			
	Machias.		*Castine.*	
	Starboard.	Port.	Starboard.	Port.
Volume swept by H.P. piston per stroke, cubic feet	2.71	2.71	2.72	2.72
Volume swept by I.P. piston per stroke, cubic feet	5.52	5.55	5.56	5.53
Volume swept by L.P. piston per stroke, cubic feet	13.45	13.43	13.385	13.435

	Machias.		*Castine.*	
	Starboard.	Port.	Starboard.	Port.
Ratio of net area of H.P. to I.P. piston	2.041	2.052	2.05	2.038
Ratio of net area of I.P. to L.P. piston	2.437	2.419	2.404	2.426
Ratio of net area of H.P. to L.P. piston	4.973	4.965	4.927	4.945
Clearance H.P. cylinder, per cent	16.96		16.96	
Clearance H.P. cylinder, inches of stroke	4.07		4.07	
Clearance I.P. cylinder, per cent	19.84		19.84	
Clearance I.P. cylinder, inches of stroke	4.76		4.76	
Clearance L.P. cylinder, per cent	11.24		11.24	
Clearance L.P. cylinder, inches of stroke	2.70		2.70	

Piston rods, diameter, inches	$3\frac{1}{8}$
Piston rods, length from piston to crosshead, inches	33
Connecting rods, length from center to center, inches	48
Connecting rods, diameter of upper end, inches	$3\frac{1}{2}$
Connecting rods, diameter of lower end, inches	$4\frac{3}{4}$
Connecting rods, thickness (sides and faces), inches	$3\frac{1}{8}$
Connecting rods, crosshead bolts (4), diameter, inches	$1\frac{1}{2}$
Connecting rods, crank-pin bolts (2), diameter, inches	2
Cross-head surface ($8\frac{1}{2} \times 10\frac{1}{4}$), square inches	87.125
Cross-head pins, diameter, inches	$3\frac{1}{2}$
Reversing gear, steam cylinder, diameter, inches	7
Reversing gear, hydraulic cylinder, diameter, inches	$3\frac{1}{2}$
Reversing gear, stroke, inches	9

Shafting.—All the crank, line and propeller shafting is of forged steel, with an axial hole through shafting and crank pins. The crank shaft for each engine is in three interchangeable and reversible sections, bolted to each other and the thrust shaft by six steel bolts. The after end of the shaft is enlarged and bored to receive the end of the propeller shaft, which is secured to it by feathers and a screw coupling. The stern shaft is cased with composition for its entire length, and the propeller shaft only where it passes through the strut. The thrust bearing is of the collar-thrust type, and is lined with white metal. The pedestal is formed into an oil trough, fitted with a cooling coil and stuffing box for confining the oil. Both forward and aft of the thrust collars there is a composition bearing, lined with white metal, for taking the weight of the shaft.

Crank shaft, diameter, inches	7
Crank shaft, axial hole, inches	$3\frac{1}{2}$
Crank shaft, coupling discs, diameter (all), inches	$13\frac{3}{4}$
Crank shaft, coupling discs, thickness (all), inches	$1\frac{7}{8}$

Crank shaft, coupling bolts, diameter (all), inches..... $1\frac{5}{8}$
Crank shaft, journals, diameter, inches..... 7
Crank shaft, length of each section, inches..... 37
Crank pins, diameter, inches..... 7
Crank pins, length, inches..... $7\frac{1}{2}$
Crank pins, axial holes, inches..... $3\frac{1}{2}$
Crank webs, thickness, inches..... $4\frac{1}{2}$
Crank webs, width, inches..... 8
Crank webs, length, inches..... 20
Crank-shaft bearings, total length, inches..... 42
Thrust shaft, diameter, inches..... $6\frac{3}{4}$
Thrust shaft, axial hole, inches..... $3\frac{1}{2}$
Thrust shaft collars, number each shaft..... 8
Thrust shaft collars, diameter, inches..... $9\frac{1}{2}$
Thrust shaft collars, thickness, inches..... $1\frac{1}{4}$
Thrust shaft collars, distance between, inches..... $1\frac{3}{4}$
Thrust surface, one engine, square inches..... 251.33
Distance from center of L.P. crank pin to center of collar thrust, feet and inches.. 4–8
Thrust shaft, length of collar section, feet and inches..... 9–5
Thrust shaft, length of after section, feet and inches..... 11–9
Propeller shaft, diameter, inches..... 7
Propeller shaft, length of forward section, feet and inches..... 21–$2\frac{1}{2}$
Propeller shaft, length of after section, feet and inches..... 23–$0\frac{5}{8}$
Propeller shaft, axial hole, diameter, inches..... $3\frac{1}{2}$
Propeller shaft, axial hole in taper part, inches..... $1\frac{1}{2}$
Propeller shaft, diameter of coupling, inches..... $13\frac{3}{4}$
Propeller shaft, diameter of coupling bolts (6), inches..... $1\frac{5}{8}$
Length of bracket bearings, inches..... 30

Propellers.—The propellers are three-bladed, the boss of composition and the blades of manganese bronze, secured to the boss by six $1\frac{1}{2}$-inch Tobin bronze bolts, secured by lock plates. The general shape of the blades is elliptical, and they are bent back at the periphery $3\frac{3}{8}$ inches from perpendicular. The boss is secured to the shaft by taper keys and a composition nut, and the end is covered with a composition cap.

Number of blades..... 3
Diameter, feet and inches..... 7–8
Diameter of hub, feet and inches..... 1–10
Length of hub, inches..... 17

	Machias.	*Castine.*
Pitch as set (adjustable from 8 feet 4.6 inches to 9 feet 4 inches), feet and inches.....	8–10.3	8–8.85
Greatest width of blade (2 feet 1 inch from axis), feet and inches.....	2–1	2–1

	Machias.	*Castine.*
Helicoidal area, mean of both screws	15.441	15.405
Disc area, square feet	46.164	46.164
Projected area, square feet	10.972	10.972
Pitch ÷ diameter	1.141	1.137
Helicoidal area (mean) ÷ disc area	.3329	.3337
Protected area ÷ disc area	.237	
Disc area (both screws), ÷ I.M.S	.351	
Center of hub above base line, feet	4	
Immersion of center at mean draught (12 feet 0⅜ inches), feet	8	
Center from center line of ship, feet and inches	3–9	

Condensers.—The main condenser shell is cylindrical, of composition, in two equal sections bolted together. It is placed abaft and immediately between the two main engines, with the tubes running athwartship and parallel to the axis of the condenser. The circulating water enters on the starboard side at the bottom, and returns in the upper half, the inlet chest being divided for that purpose. There are straightway valves connecting each exhaust pipe to the condenser, so that in case of accident to either engine the vacuum may not be impaired by leakage. The auxiliary exhaust is also connected with the condenser, and the main condenser can be used for auxiliary purposes.

Diameter of shell (inside), feet and inches	4–3
Length over heads, feet and inches	8–4
Tubes, length between heads, feet and inches	6–9½
Tubes, diameter outside, inch	⅝
Tubes, number	2,027
Tube sheet thickness, inch	⅞
Condensing surface, square feet	2,246
Ratio of cooling surface to heating surface	1 to 2.04

There is also an auxiliary condenser fitted with a horizontal combined air and circulating pump of the Blake type. It is placed outboard of the main engines on the port side of the engine room. Its principal dimensions are:

Diameter (copper condenser), inches	17⅝
Length (over all), feet and inches	5–7⅝
Tubes, length between sheets, feet and inches	4–8
Tubes, diameter outside, inch	⅝
Tubes, number	194

Tube sheet thickness, inch	$\frac{7}{8}$
Condensing surface, square feet	150
Combined pump:	
Steam cylinder diameter, inches	$6\frac{1}{2}$
Water cylinder (circulating), inches	8
Air-pump cylinder, inches	8
Stroke, common, inches	8
Diameter of piston rod, inches	$1\frac{1}{4}$

Air Pump.—The main air pumps are double-vertical pumps of the Bureau design, driven by a pair of inverted steam cylinders, with cranks at an angle of 90°. The air-pump channelways have a nozzle, to which are connected the main and auxiliary feed pumps, so that either of these pumps can draw directly from the main condenser when used for auxiliary purposes.

Diameter of steam cylinders each, inches	$6\frac{1}{4}$
Diameter of piston rod, inches	$1\frac{1}{2}$
Diameter of each pump cylinder (2), inches	$13\frac{1}{2}$
Stroke, common, inches	12

Circulating Pump.—The circulating pump is of the double-inlet centrifugal type driven by a pair of inverted, vertical, simple engines, arranged to draw either from overboard or from the bilge, and to discharge either into the condenser or directly overboard, straightway valves being fitted for this purpose.

Diameter of engine cylinders (each), inches	4
Diameter of piston rods, inch	$\frac{7}{8}$
Stroke, inches	5
Diameter of fans, inches	20
Diameter of inlet, outlet and discharge, each, inches	8

Turning Engine.—A small turning engine is placed in the passage-way between the two engines, and turns the main engine by means of a worm gear. The engines are double, 4 inches diameter of cylinder × 5 inches stroke, and are arranged for disconnecting, so that the engine may be turned by hand-ratchet gear.

Feed Pumps.—The main feed pump is placed in the fire room, and the auxiliary feed on the port side of the engine room, outboard of the engine. Both are of the Blake vertical-duplex type. The main feed is arranged to deliver the feed water directly to

boilers, or through the feed-water heaters in each uptake. The auxiliary feed delivers the water direct to the boilers only, through a separate feed pipe.

Other Auxiliary Machinery.—There is a main fire and bilge pump, and an auxiliary fire pump on the starboard side of the engine room; this latter pump also serving as a water service pump for the engines, but does not connect to the bilge. Both of these pumps are of the Blake vertical-duplex type.

A horizontal Davidson pump is placed in the forward part of the engine room, and is used as a flushing pump for the water closets and bath rooms. It also acts as a circulating pump for the distiller, a by pass being fitted for this purpose.

Distilling Apparatus.—The distilling apparatus consists of a Baird's evaporator and distiller (No. 3, type C), with a rated capacity of 2,000 gallons of potable water per day. It is situated in the engine room, forward, in a pocket taken from the coal bunker. The evaporator is vertical, with U-shaped tubes placed horizontally. There is a 3½-inch pipe leading to the main condenser, for making up the loss of feed water. The circulating pump to the distiller discharges either into the flushing system or directly overboard. The evaporator feed takes its water from the distiller discharge circulating water, and the tank pump takes its suction from the filter through a water meter, and discharges into the ship's tanks and into the firemen's wash room.

The following shows the tabulated dimensions of the various pumps in the engine and fire rooms:

		Steam cylinder.	*Water cylinder*	*Stroke.*
Main feed, inches	Blake.	7½	4½	8
Auxiliary feed, inches	Blake.	7½	4½	8
Main fire and bilge, inches	Blake.	8	5	12
Auxiliary fire and water service, inches	Blake.	6	4	7
Distiller circulating pump, inches	Davidson.	5½	5	8
Evaporator feed, inches	Davidson.	2½	1½	3
Evaporator to ship's tanks, inches	Davidson.	3½	2	4
Evaporator to feed tanks, inches	Davidson.	2½	1½	3

Ash Hoist.—The ash hoist is a Williamson single-cylinder engine, placed over the after part of fire room compartment.

There is an outfit for a small workshop (not yet located) consisting of a lathe, drill press and vise bench, the power being furnished by a small vertical engine $3\frac{1}{8}$ inches diameter by $3\frac{3}{4}$ inches stroke.

Forced Draft.—The forced draft is on the closed fire-room system, air being supplied by two Sturtevant blowers, situated in pockets between the engine and fire rooms. They take air from the two fire room ventilating shafts and the engine room, and deliver it directly into the fire room, screens being fitted near the end of the boilers to reduce the space kept under pressure. The fans are driven by vertical, enclosed double engines.

Diameter steam cylinders (two), inches	5
Stroke, inches	4
Diameter of fans, inches	45
Area induction nozzle (24 inches diameter), square inches	452.39
Area eduction nozzle (16 inches diameter), square inches	201.06

Ventilation.—There are two Sturtevant blowers, one aft and the other forward, for ventilating the living space in the ship, which are of the same type as those used for forced draft, arranged to exhaust the air.

Diameter of steam cylinders (two), inches	$3\frac{1}{2}$
Stroke, inches	$2\frac{1}{2}$
Diameter of fans, inches	28
Area induction nozzle, square inches	240.53
Area eduction nozzle, square inches	180.00

Revolution Counters and Tell-tales.—The main engine counters receive their motion from the main shaft by links and levers, ball-and-socket joints being used. Peabody shaft indicators are located on the poop and in the pilot house, the transmitting mechanism being in the shaft alleys.

Electrical Plant.—The ship is furnished with two dynamos of the compound-wound, bi-polar type. Their capacity is 50 amperes each, produced by an electro motive force of 80 volts. Each dynamo is driven by a two-cylinder simple engine of the vertical inverted type. The dynamos and engine are mounted on the same bed plate, and the dynamos are direct-driven, the

armature being solidly coupled to the engine shaft. A single piston valve supplies steam to both cylinders of each engine.

The armature revolves at a speed of about 480 revolutions per minute to produce the required output of the machine.

The ship has 172 lights, besides the search lights and signals; the total candle power of the 172 lights being 2,348.

The lights are arranged in six sections, the mains of each section, as well as those of the search lights and signals, being carried to the switch board in the dynamo room. The switch board is so arranged that the mechanism may be run separately or in parallel, and so that any section may be thrown on either machine at any time.

Besides this lighting plant the ships have a very complete equipment of call bells and voice pipes, and a fire and water-alarm system, and are fitted with shaft and rudder indicators.

Windlass and Capstan Engine.—Is of the type known as the "Hyde Steam Capstan Windlass," and is manufactured by the Bath Iron Works. The *Castine* and *Machias* are the first vessels of the Navy in which these capstans have been placed, and from the tests to which they have been subjected, they seem reliable, and perform their work thoroughly. The following is a brief description of the machine: Cylinders, 7 inches diameter and 8 inches stroke. The windlass and engine are complete on one bed plate, making the entire machine self-contained. Double engines of the piston-valve type are used, with the cylinders at right angles to each other, and making angles of 45 degrees with the bed plate.

The windlass may be driven by hand from the decks above by a capstan, which is connected with the windlass by means of the upright capstan shaft engaging a worm gear on the windlass shaft. There is no necessity for disengaging gear for either steam or hand power, as it is so arranged that the windlass is always ready for use, either by hand or steam power, without changing any of the parts.

In addition to the regular purchase (which is sufficient to raise both anchors at the same time under ordinary circumstances), a double purchase can be obtained, for use in an emergency, by

applying the power from the engine first to the capstan shaft and then to the windlass shaft, through the worm and wheel by which the hand power is applied.

The wild-cats over which the cables run are locked and unlocked by a positive screw-locking device, and may be unlocked easily, even with a heavy strain on the cables. The wild-cats, in "paying out," are controlled by friction bands with powerful brakes, and the whole strong enough to "ride by."

The capstan connected with the windlass is driven direct from the engine shaft by worm gearing, in the manner usually applied to independent steam capstans. Just forward of the engine, on the main shaft, is keyed a heavy balance wheel to insure smooth running. The engine is instantly reversible.

All bearings are of phosphor bronze or magnolia metal. The worm wheel and worm are machine cut, the worm being of the "hour-glass" type, and so cut that a perfect surface contact is obtained between the worm and wheel the entire length of the worm.

Boilers.—The boilers are of the marine locomotive type, each having two furnaces with flat inclined sides and flat top, a common combustion chamber and hanging bridge. The front and back heads are rounded to reduce the weight of longitudinal bracing. The longitudinal shell joints are treble riveted with double butt straps. The circumferential seams are lapped and double riveted. The furnaces are fitted with the Bannister rocking grate, and the boilers are designed for a working pressure of 160 pounds per square inch.

Each boiler is fitted with a feed-water heater, consisting of two horizontal rows of brass pipe in each uptake. The feed water from the main feed pump is sent through the feed pipe into the coils, where it is heated by the escaping chimney gases, and returns to the main check, through which it enters the boiler near the end. A two-way valve and connecting pipe is fitted to the main feed pipe, so that the feed water may be shut off from the heater and feed direct to the boiler through the main check valve.

This apparatus is also utilized as a device for assisting the cir-

culation of water while raising steam. For this purpose a pipe is led down to the lower part of the boiler from any part of the feed pipe before it enters the heating coil. This hanging pipe is fitted near the bottom with a stop and check valve. The boiler being filled and fires started, the contained water in the feed-heating coil is expanded and moves towards the boiler, at the same time inducing a current from the bottom of the boiler through the hanging pipe to the feed heater, producing a natural and easy circulation.

Number of boilers to each ship	2.
Heating surface (total), square feet	4,590.
Grate surface (total), square feet	120.
Ratio H.S. to G.S.	38.25
Area of smoke pipe (56 inches diameter), square feet	17.104
Height of funnel above grate, feet and inches	50–3
Ratio of grate to area through tubes	7.22
Length of boiler (extreme), feet and inches	18–6
Diameter, cylindrical, feet and inches	9–3
Length of front, feet and inches	7–11½
Width of front, feet and inches	10–7½
Height of front, to top of shell, feet	8–0
Thickness of shell, inch	$\frac{7}{8}$
Thickness of front head, inch	$\frac{9}{16}$
Thickness of butt straps (outside), inch	$\frac{13}{16}$
Thickness of butt straps (inside), inch	$\frac{1}{2}$
Combustion chamber, thickness of plates, inch	$\frac{1}{2}$
Combustion chamber, length, feet and inches	3–3½
Combustion chamber, width, greatest, feet and inches	8–1
Combustion chamber, width, least, feet and inches	2–9
Combustion chamber, height, inside, feet and inches	5–1
Furnace, height above grate, front, feet and inches	3–8½
Furnace, height above grate, back, feet and inches	4–9
Furnace, width at grate, feet and inches	4–6
Furnace, length, feet and inches	6–9¼
Thickness of furnace sheets, inch	$\frac{1}{2}$
Grate, length, feet and inches	6–9
Grate, width, feet and inches	4–6
Grate, pitch of, inches	7
Grate surface, one boiler, square feet	60.00
Tube sheet, front, thickness, inch	$\frac{13}{16}$
Tube sheet, back, thickness, inch	$\frac{3}{4}$
Tubes, number, one boiler, ordinary	408
Tubes, number, one boiler, stay	80

Tubes, thickness, ordinary	No. 13 B.W.G.
Tubes, thickness, stay	No. 6 B.W.G.
Tubes, diameter, outside, inches	2
Tubes, length between sheets, feet and inches	7–10$\frac{7}{16}$
Tubes, area through, one boiler, square feet	8.31
Hanging bridge, distance from tube sheet, inches	12$\frac{1}{2}$
Hanging bridge, depth at center, inches	15$\frac{1}{2}$
Hanging bridge, thickness, inches	6$\frac{1}{2}$
Water space between furnaces, width, inches	5$\frac{1}{2}$ to 9
Water legs, sides, inches	5 to 6$\frac{1}{2}$
Water space between combustion chamber and shell, inches	5
Heating surface, tubes (one boiler), square feet	2,011
Heating surface, front tube sheet (one boiler), square feet	26
Heating surface, combustion chamber (one boiler), square feet	76
Heating surface, furnaces, 2, (one boiler), square feet	182
Heating surface, total (one boiler), square feet	2,295
Feed water heater, square feet	62
Diameter of longitudinal braces, inches	2$\frac{1}{4}$
Number of longitudinal braces	7
Number of transverse braces	6
Diameter of transverse braces, inches	1$\frac{3}{4}$
Locomotive girder stays, length, inches	38
Locomotive girder stays, depth, inches	11
Diameter of safety valve (one double valve on each boiler), Crosby, inches,	2$\frac{1}{2}$
Weight of one boiler (empty), tons	22$\frac{1}{2}$
Weight of water at steaming level, tons	11
Total weight of one boiler, tons	33$\frac{1}{2}$

Coal Bunkers.—There are 13 coal bunkers—of these, 7 are below the water-tight deck, 3 on each side of the engine and boiler compartments—and a small pocket between the engine and fire room on the port side. Above the water-tight deck there is a port and starboard bunker over the engine room; a center bunker extending across the ship, between engine-room bulkhead and that at the fire-room hatch; forward of this is a similar athwartship bunker, between the bulkheads at fire room and smoke-pipe hatches, and a side bunker on each side of the smoke-pipe hatch. The upper bunkers trim into the lower, and are fitted with trunks and water-tight doors in the water-tight deck, and slide doors to the bunkers above the water-tight deck.

The estimated capacity of the lower bunkers is, tons, .	55.16
The estimated capacity of the upper bunkers is, tons, .	118.12
Total capacity, tons, ...	173.28

In addition to the above, coal in bags may be stowed in the starboard and port wing passages leading forward and aft on the berth deck, and the coal capacity increased by about 30 tons.

WEIGHTS.

	Machias.	*Castine.*
Propelling machinery, tons	128.7376	129.7218
Water in above machinery, boilers 6 inches above highest heating surface, tons	27.5314	26.9445
Stores, tools, instruments and duplicate pieces, tons	2.4209	2.3995
Miscellaneous machinery, tons	14.9717	14.8380
Total, tons	173.6607	173.8998

The following are the most important detailed weights:

	Pounds.
Bed plates, frames, crank-shaft bearings	10,796
Crosshead guides	1,444
Cylinders	15,389
Cylinders, relief valves, chains, clothing, etc.	2,041
Pistons, piston rods and nuts	1,744
Crossheads	959
Connecting rods	2,735
Valve gear, stems, links, eccentrics, etc.	4,578
Reversing gear and engine	2,358
Crank shafts	4,124
Line shafts	2,672
Thrust shafts	2,404
Propeller shafting, two sections, casing and couplings	10,336
Bearings, thrust	2,193
Bearings, shaft and stern tube	2,349
Bearings, bracket	754
Propellers	4,473
Oil service	434
Water service, pipes and valves	976
Main steam-pipe bleeders and passover	1,554
Separators and traps	1,641
Main condenser and small attachments	9,755
Circulating pump, connections and engines	2,974
Air pump and connections	4,951
All outboard valves	1,403
Feed tank, etc.	1,131
Main feed pump	1,310
Boilers	106,078
Grate bars, furnaces, ashpit doors, etc.	14,976
Bridges, gauges, clothing, etc.	7,902

	Pounds.
Stop valves, auxiliary checks, blow valves and piping	1,121
Water in boiler 6 inches above tubes (12.13 tons each)	54,368
Safety valves, escape pipes, muffler and whistles	1,283
Smoke pipe, uptakes and doors	19,921
Blowers, air ducts, etc., for forced draft	2,643
Ventilators, with closing dampers complete, fire room	3,072
Ventilators, engine room	1,206
Ash hoist	1,252
Feed-water heater and circulating apparatus	2,030
Auxiliary feed and connections	2,289
Auxiliary fire pump (with fire main)	1,645
Fire and bilge pump (with fire main)	2,483
Turning engine	1,166
Auxiliary condenser	1,001
Auxiliary condenser pump and connections	1,555
Distilling and evaporating plant	3,323
Auxiliary steam and exhaust piping	3,374
Engine room floor and ladders	4,871
Fire room floor and ladders	4,548

TRIAL.

The official trial of the *Castine* was made on September 15, 1893, and consisted of two successive runs over a measured course of about 30 knots in length, beginning at a point southward of Stratford shoal and running to a point off Saybrook Light house, Long Island Sound. No preliminary trial over the course was made, the contractors not thinking it necessary.

The *Castine* left New London at 10.40 A. M.; steamed out towards the course under natural draft, and passed the first stake boat at 1 hour 21 minutes and 39.5 seconds. Through some misunderstanding among the contractors' force, the ship crossed the line before they were ready in the engine room, the steam pressure being but 125 pounds, and the revolutions of the main engines 190; but in a few minutes the blowers brought the pressure up to 160 pounds, when the throttles were opened wide and the revolutions increased to 220, and varied between this and the maximum during the run.

The trial passed off without accident, except the carrying away of the counter gear of the starboard engine, during the first fifteen minutes, so that for the run, the revolutions of the starboard engine were counted by hand, a mean of three counts

being taken, which, at the high speed, 223–225 revolutions, made it difficult to get very accurate results.

The coal used was selected Pocahontas, carefully weighed and bagged; it burned freely, made no clinker and but little refuse.

The main engines, boilers and auxiliaries worked very satisfactorily. No water, except the regular circulation through the hollow brasses and guides, was used on any of the bearings of the main or auxiliary machinery, except a slight stream on the thrust blocks as a precautionary measure, and a stream on the L.P. eccentrics, for a few minutes to check a heating tendency.

The performance of the independent air pump, the circulating pump, blowers, feed pump and other auxiliaries was very good, with no heating and no mishaps, the air pump making a good vacuum at a moderate speed, 120 revolutions, and giving no trouble whatever.

The boilers were in operation during the trial under forced draft; they steamed freely, showed no signs of foaming, and during the trial were quite tight. It became necessary at intervals to slacken the speed of the blowers and open the furnace doors slightly, in order to keep the pressure down to the required limit.

The amount of ashes made during the trial could not be ascertained with sufficient accuracy to be of any value.

A standard steam gauge from the New York Navy Yard was attached to the starboard boiler, and the pressure was not allowed to exceed the limiting pressure, 168 pounds, at any time.

Two feed-supply tanks, located on deck, were connected to the feed tank in the engine room, and were heated from the auxiliary steam pipe by pipes entering at the bottom. Previous to the trial the water in these tanks was heated to about 137°.

Indicator cards were taken from each end of the main cylinder every half hour, and from the air pump every hour, the revolutions being carefully counted at the same time the cards were taken. The attempts to take cards from the circulating pump were fruitless, owing to the high speed (465 revolutions) and the inefficiency of the indicating gear. On the day following the trial a card was obtained at 415 revolutions, and was used in the

computation of the trial, correcting the I.H.P. for the speed. Cards taken from the feed pump and blowers after the trial were unsatisfactory, and the I.H.P. for these auxiliaries was estimated.

The start from New London was made in a misting rain, with the wind S.S.E., and with prospects unfavorable to good weather. A light fog hung over the Sound that gradually lifted before noon, the wind shifting to S.S.W., and the sea only moderately smooth. On the first run the wind was on the bow, and on the return run it was astern; its force throughout the trial varying from 4 to 5.

Left New London,		10.40 A. M.
First transit,	Going,	1 hour 21 minutes 39.5 seconds.
Second transit,	Going,	3 hours 13 minutes 37.3 seconds.
Third transit,	Returning,	3 hours 27 minutes 5 seconds.
Fourth transit,	Returning,	5 hours 13 minutes 56.2 seconds.
Arrived off New London,		7.00 P. M.

The trial crew in the Engineer Department, under Chief Engineer S. P. Hinckley, was composed of the following; 2 assistant engineers; 7 oilers; 4 machinists; 4 firemen; 3 coal passers.

Since the trial, the boilers, main cylinders, valves, journals of main engines, the feed, air and circulating pumps have been examined and found in excellent condition. A few slight leaks were found in the boiler seams and rivets, slight leaks among the top rows of tubes and a number of ferrules gone.

The corrected speed averaged for the four hours 16.032 knots. By the terms of the contract the air pressure was limited to $\frac{1}{2}$ inch, but, during the trial, this pressure was allowed to average 1.4 inches, and the contractors in preference to the expense of a new trial, accepted the Department's comparative estimate, based on the performance of other ships, and the vessel was accepted with an official speed of 15.61 knots, 2.61 knots above the contract requirements.

The performance of the vessel under way was admirable. She steered extremely well, and the hull vibrations were found, even at the high speed, to be almost imperceptible.

In explanation of the great increase not only in speed, but also in I.H.P. over the contract requirements, the same condition existed at the time the designs were made for these gunboats as in the *Bancroft*. It was expected that the air pressure would be an inch or over, as in the case of the *Yorktown*, the original speed being for the *Bancroft* 13 knots and the gunboats 14 knots. After the designs were finished the air pressure was reduced, and it became necessary to fix upon a new contract speed. No data were available of accurate trials with ½-inch pressure, and an estimate was based upon the *Yorktown's* performance. It was supposed that 12½ knots could be obtained in the case of the *Bancroft* and 13½ knots with the gunboats, and in accordance with the Department's practice of allowing a slight margin for unforeseen contingencies, 12 knots and 13 knots were fixed as the contract speed for the *Bancroft* and the gunboats respectively.

The use of the locomotive boiler was also an important factor, as with the large amount of plate-heating surface the evaporation was materially increased beyond that due to the same *total* heating surface in the ordinary type of boiler.

MACHIAS.

The official trial of the *Machias* was made on June 10th, 1893, over the same course used by the *Castine* and under the same conditions. The boilers steamed freely and the engines worked well during the trial, with the exception of the air pump, whose performance was not very satisfactory. Owing to the irregularity of its action it became necessary to run it at a very high speed in order to prevent it from stopping and to maintain the vacuum.

No mishaps occurred to interfere with the performance except the slackening of the nuts securing the ahead to the backing eccentric on the port intermediate engine, necessitating the stoppage of the port engine for three minutes while these nuts were set up.

On the port blower a cylinder relief valve blew out, and some trouble was experienced in the heating of the crank-pin brasses of the engine of this blower.

The average corrected speed for the four hours was 15.46 knots, an advance over the contracted speed of 2.46 knots.

DATA OF TRIAL.

	Machias.	*Castine.*
Draught at beginning, feet and inches { Forward		10–8½
{ Aft		13–0
Draught at end, feet and inches { Forward		10–5
{ Aft		13–0
Draught, mean for trial, feet and inches { Forward	10–6¾	10–6¾
{ Aft	13–0	13–0
Displacement at mean draught on trial, tons	1,067.5	1,067.5
Area of immersed midship section, square feet	324.64	324.64
Wetted surface, square feet	6,816.	6,816.
I.H.P., total, per 100 square feet of wetted surface	27.48	32.13
I.H.P., total, per 100 square feet of wetted surface reduced in the ratio of 3.5 power	5.977	6.159
Average speed in knots	15.464	16.032
	Starboard. Port.	Starboard. Port.
Slip, per cent	19.05 17.44	14.32 15.71
$S^3 \times$ area of immersed midship section ÷ I.H.P., (main engines, air and circulating pumps)	655.57	618.7
$S^3 \times$ (displacement) $^{\frac{2}{3}}$ ÷ I.H.P	210.93	199.06

SYNOPSIS OF STEAM LOG.

	Machias.		*Castine.*	
	Starboard.	Port.	Starboard.	Port.
Revolutions of main engine per minute	218.55	214.27	217.00	220.59
Piston speed in feet per minute	874.20	857.08	868.00	882.36
Steam pressure at boilers, per gauge	163.2		163.	
Steam pressure at engines, per gauge	159.5		153.	
Steam pressure at first receiver, absolute,	91.2	106.2	93.2	95.53
Steam pressure at second receiver, absolute	34.7	36.6	38.00	38.75
Vacuum in condenser, inches of mercury	25.7		25.3	
Opening of throttle	Wide.	Wide.	Wide.	Wide.
Steam cut-off in fraction of stroke, from beginning, H.P.	.8	.8	.7 to .8	.7 to .8

	Machias.		*Castine.*	
	Starboard.	Port.	Starboard.	Port.
Steam cut-off in fraction of stroke, from beginning, I.P.	.8	.8	.8	.8
Steam cut-off in fraction of stroke, from beginning, L.P.	.8	.8	.8	.8
Double strokes of air pump per minute	223.53		120.59	
Double strokes of feed pump per minute,	81.		70.21	
Revolutions of circulating pump, per minute	513.7		451.00	
Temperature, degrees, Fahrenheit. Engine room	103.		102.	
Injection	65.		72.	
Discharge	101.		110.	
Hot well	116.		115.	
Feed at boiler	160.		122.	
Fire room	106.		114.	
Revolutions of blowers per minute	589.5		582.	723.67
Mean pressure in cylinders. High pressure	48.35	45.28	39.70	31.17
Intermediate pressure,	23.48	27.88	30.79	32.11
Low pressure	14.72	16.62	21.94	21.47
Aggregate equivalent referred to L.P.	33.93	37.03	42.58	40.82
I.H.P. H.P. cylinder	245.56	224.43	200.36	159.84
I.P. cylinder	245.55	286.69	321.70	338.90
L.P. cylinder	376.44	415.82	553.98	553.15
Collective, each main engine,	867.55	926.94	1,076.04	1,051.89
Collective, both main engines,	1,794.49		2,127.93	
Air pump	17.94		14.07	
Circulating pump	15.73		20.00	
Feed pump	19.75		18.30	
Blowers (estimated)	23.20		16.85	
Other auxiliaries (estimated),	2.30		2.10	
Collective I.H.P. of all auxiliaries	78.92		71.32	
Collective I.H.P. of all machinery in operation (mean)	1,873.41		2,199.25	
Indicated thrust (main engines only), pounds	14,787.33	16,115.92	18,726.9	18,012.5
Indicated thrust per square foot of developed area of propeller, pounds	957.70	1,043.75	1,215.7	1,169.3
Indicated thrust per square inch of thrust bearing, pounds	58.84	64.13	74.51	71.67
Square feet of cooling surface per I.H.P., main engines and main condenser	1.20		1.03	
Square feet of heating surface per I.H.P., all machinery	2.45		2.09	

	Machias.		*Castine.*	
	Starboard.	Port.	Starboard.	Port.
Cubic feet per minute swept by L.P. piston per I.H.P.	6.78	6.21	5.40	5.63
I.H.P. per square foot of G.S. (all machinery in operation)	15.61		18.33	
I.H.P. per ton of boilers, water fittings and all fire-room weights, tons	19.15		22.53	
I.H.P. per ton of propelling machinery, boilers and water, tons	11.98		13.98	
COAL.				
Pounds per hour	4,569.12		5,108.04	
Pounds per hour per I.H.P., collective, all machinery	2.44		2.32	
Pounds per hour per I.H.P., collective, main engine, air, circulating and feed pump	2.47		2.34	
Pounds per hour per square foot of G.S.	38.08		42.56	
Pounds per hour per square foot of H.S.	0.99		1.11	

ON THE MEASUREMENT OF WAKE CURRENTS.

By George A. Calvert, Esq.

[Read at the Thirty-fourth Session of the Institution of Naval Architects, July 13, 1893.]

The investigation of the relative speeds of the water in different portions of a ship's wake is a subject which has hitherto scarcely received the attention which its importance appears to warrant, and any addition, however small, to our knowledge of the phenomena of "wake motion" will probably prove acceptable to naval architects and engineers alike.

I propose, therefore, in this paper, to describe some experiments on a comparatively small scale which I have made during the last few years, with the view of ascertaining the actual condition of the water around the stern of a moving vessel. The object of my experiments included inquiry into many points more or less intimately connected with the problem of marine propulsion, but, in consideration of the limits of time and space, I shall confine the following remarks to the simple case of a vessel being towed through water which is otherwise undisturbed, and an investigation of the nature of the currents set up in consequence of the vessel's motion.

At the outset, it appeared natural to select a full-size vessel as the subject of experiment, and, accordingly, when an opportunity offered in January, 1889, I fitted a light wire rope framework around the keel and counter of a steamer, then lying in Holyhead Graving Dock, upon which I fixed ten "Walker's towing logs." The vessel was about 260 feet in length; and, as her propeller had been removed, it was possible to arrange the logs in the space ordinarily swept by the propeller, and they were disposed so as to represent twenty different positions in that area. The steamer was towed to a graving dock in Liverpool,

and, when the dock was emptied, the readings of the ten logs were compared with that of a similar log which had been towed astern in the usual way. The records were interesting and instructive, but they did not appear to have much connection with the results anticipated by theory, and several sources of possible error suggested themselves. The speed of the vessel necessarily varied during the voyage, and the logs showed only the average of a number of different speeds; the action of the rudder would influence the stream lines, and the wash from the towing steamers might also affect the results; the logs were fixed in a fore-and-aft line, and would not accurately register the velocities of currents meeting them obliquely; and the speed at which the vessel was towed never exceeded one-half her full speed under her own steam. Even assuming that corrections could be made for each of these disturbing elements, the readings simply represented the velocities in twenty positions, in one athwartship section of the wake, and afforded no information as regards the condition of the water before or abaft that section.

In consideration of these objections to full-size experiments, and also of the improbability of many such opportunities presenting themselves in practice, I decided to construct a large model, one-ninth the lineal dimensions of a vessel whose performances were known, and to adapt this model for carrying measuring appliances which would show, from instant to instant, not only the velocity, but also the direction of the wake currents. It was necessary that the measuring apparatus should be readily adjustable, so that the condition of the water might be ascertained in all usual or probable positions occupied by single or twin screws.

The dimensions of the model were as follows: Length, 28½ feet; beam, 3.66 feet; mean load draught, 1.55 feet; displacement at that draught, 2.89 tons; wetted surface, 154.5 feet. It formed, therefore, a fair-sized boat, providing accommodation for those who conducted the experiments, and also carrying iron ballast for adjusting the trim, or varying the displacement when required. During the experiments I am about to describe, the propeller boss was fitted in place, but no blades were at-

tached. The immersed surface of the model was coated with black varnish. A cross section of the model, abreast the screw aperture, is shown at Fig. 1, which also represents the main features of the apparatus employed in measuring the wake currents.

Across the stern was fitted a framework upon which several fine vertical wires *a* were stretched, extending from the deck to some distance below the keel. Each of these wires, and the apparatus connected with it, being exactly similar to its neighbors, it will simplify the description if I refer at present to one only, and on the longitudinal section of the stern shown at Fig. 2, one of these vertical wires is again marked *a*. Upon this wire, and at the level at which the wake measurement was required, a horizontal tube *b*, $\frac{1}{8}$-inch internal diameter, was carried by a universal joint near its open forward end. The after end of this tube was in communication with another tube *c* closed at its upper and lower ends, and hung by trunnions to one end of a weighted lever *d*, Fig. 1. One of the trunnions being hollow, formed a connection through the rubber tube *e* to the underside of a gauge glass *f* inside the model, so that through this system of jointed tubes there was free communication between the gauge glass and the water outside. On the after end of the tube *b* four thin radial feathers were fixed, and as the weight of that end of the system of tubes was accurately balanced by the lever *d*, the horizontal tube necessarily assumed a position parallel to the direction of any current in which it might be placed (as a weather vane indicates the direction of the wind), and its open forward end was consequently always presented normally to the current. In order that the attitude of the submerged tube *b* might be noted by the observers in the boat, the vertical tube *c* carried a light rod *g*, the top of which indicated the inclination in any direction of the tube *b*. Four or five such horizontal tubes were fitted at one time, each on its vertical wire *a*, and having its connections as described; and another such tube with similar connections was carried by an outrigger, reaching out into water that was practically undisturbed.

As the cross-sectional area of the wake under measurement was more than 7,000 times as great as the aggregate area of the tubes *b*, the disturbing influence of the latter would be very slight.

The gauge glasses *f* were grouped together inside the boat in front of a scale of inches, and the index rods *g* had also a specially lined background. A camera was arranged so that the gauge glasses and index rods could be simultaneously photographed.

There were other details of the apparatus to which I need not refer, as they were either adopted to economize time or for other experiments not described in this paper.

The air having been sucked out of the whole system of tubes, the water in all the gauge glasses *f* stood at the same level as the surface of the river. The model was then towed at a determined speed by an engine and winch, which were fixed on a barge moored in the river, and a photograph was taken which recorded the heights of the water in the gauge glasses and the inclination of each of the horizontal tubes.

If the water into which these horizontal tubes advanced were at rest, or if its velocity throughout were uniform, then the water in the gauge glasses, rising higher and higher as the speed increased, would still stand at the same level in all the glasses. Assuming that the tube carried by the outrigger was always advancing into undisturbed water, then the water in the gauge glass connected with that tube would serve as a datum line from which at that instant the relative elevation or depression of the water in any other gauge glass could be measured, indicating for its corresponding horizontal tube that the water through which it was passing was either meeting or following the boat.

As the rise of water in the gauge glasses during these experiments was owing partially to the head corresponding to the velocity with which the horizontal tubes passed through the water, and partially to the local elevation of the river surface due to the waves at the stern, it was necessary that the exact height of this wave should be ascertained. This was done by photographing the wave profile on each side of the model, the cameras being fixed on booms projecting over the port and starboard

XU

FIG. 2.

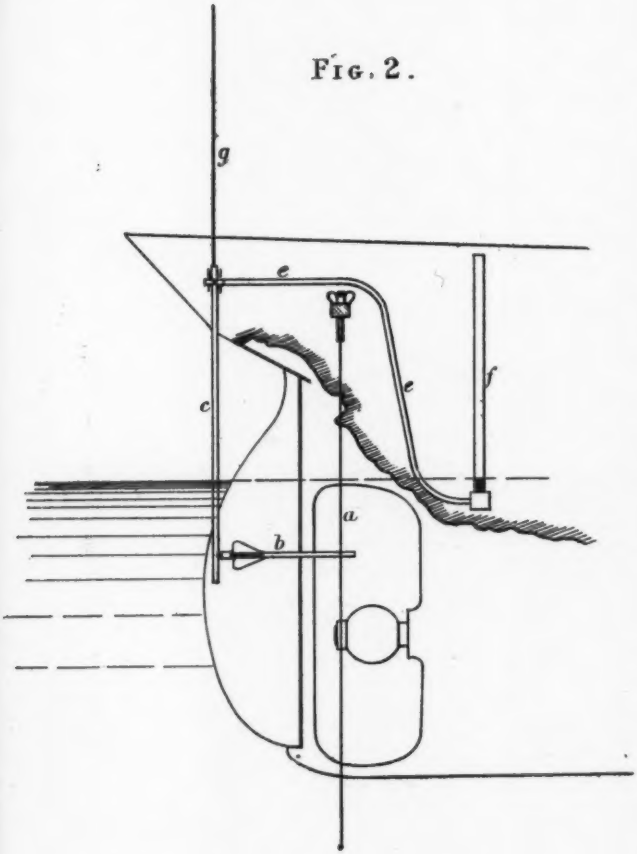


FIG. 1.

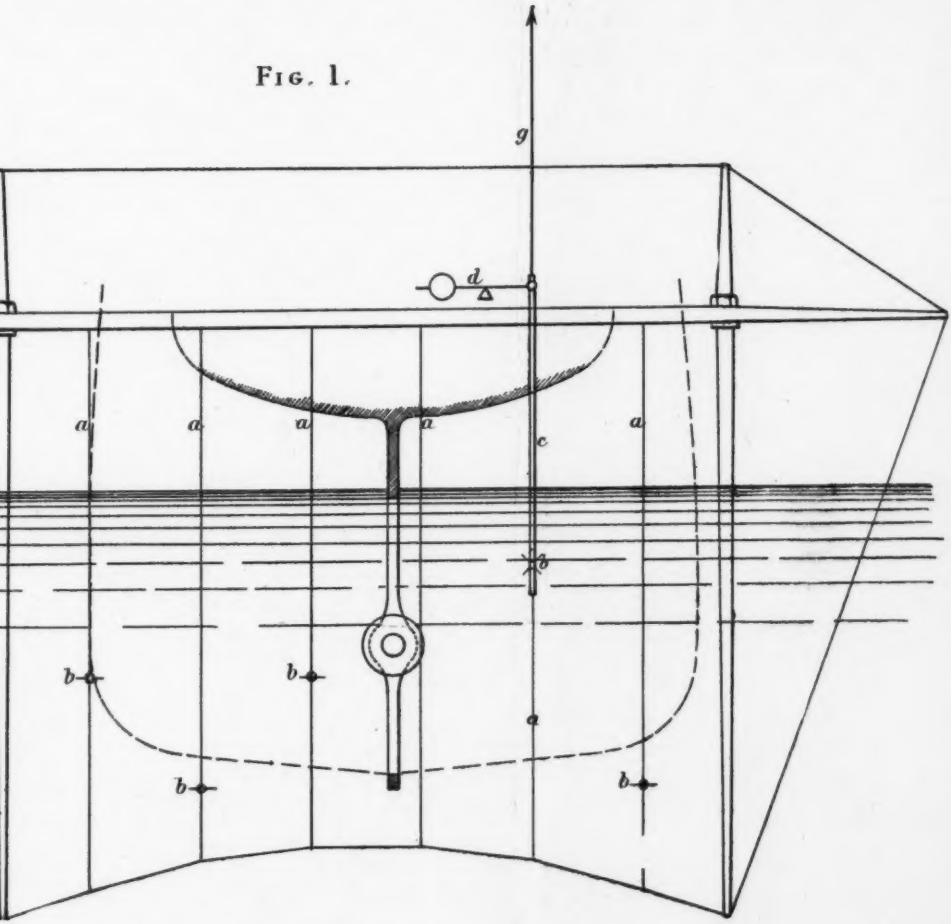
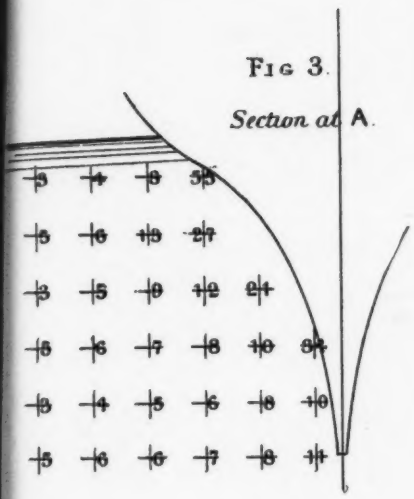


FIG 3.

Section at A.



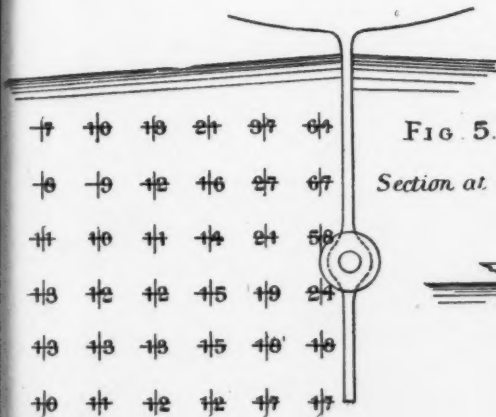


FIG 5.

Section at

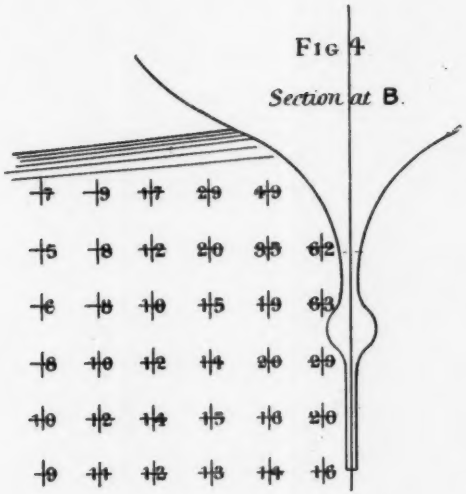


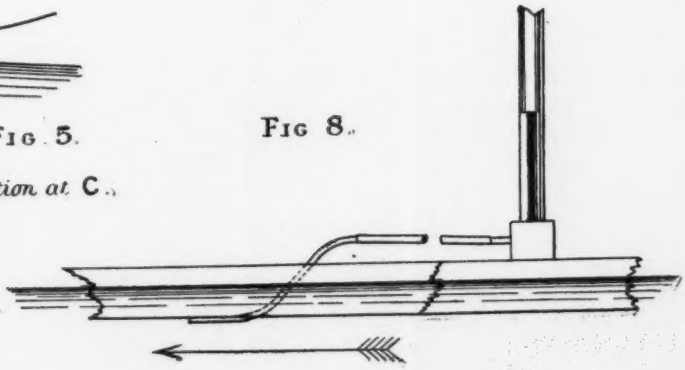
FIG 4

Section at B.

FIG 5.

Section at C.

FIG 8.



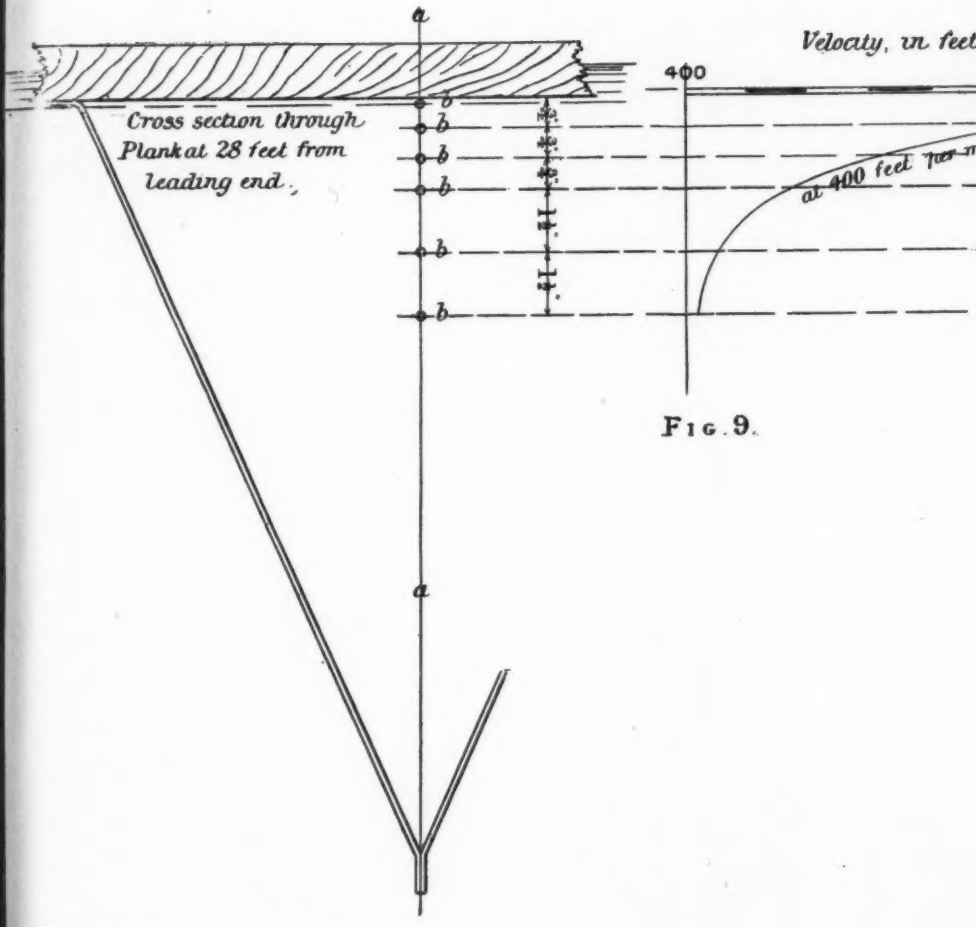
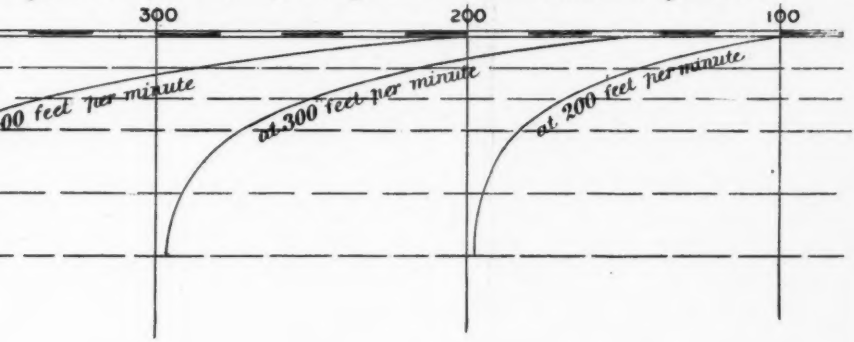

a
Velocity, in feet
400
Cross section through
Plank at 28 feet from
leading end.
b
b
b
b
b
b
at 400 feet
a

FIG. 9.

oaty, in feet per minute, through the water, as indicated by tubes "b."



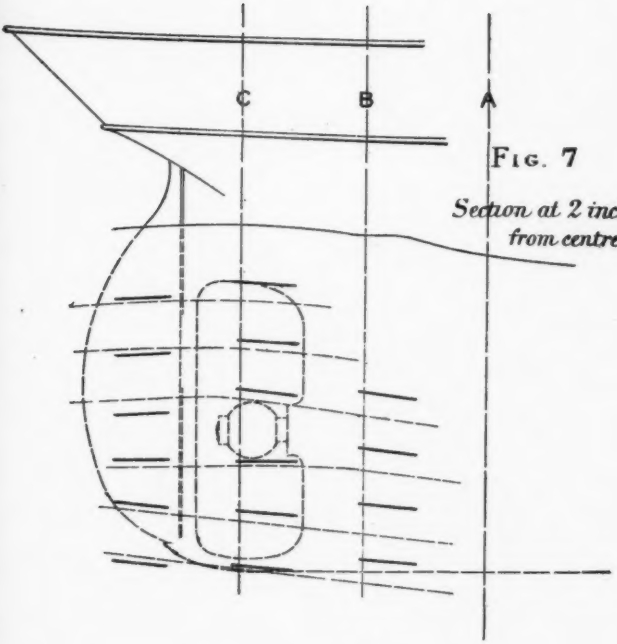


FIG. 7

Section at 2 inches out from centre

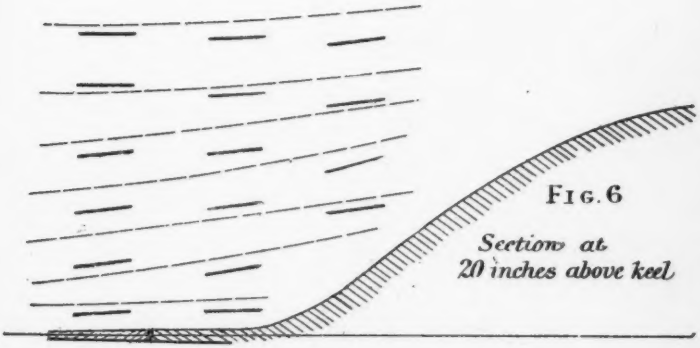


FIG. 6

Section at 20 inches above keel

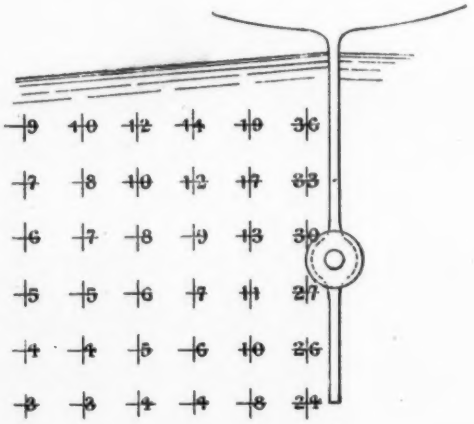

9 10 12 14 19 36
7 8 10 12 17 33
6 7 8 9 13 30
5 5 6 7 11 27
4 4 5 6 10 26
3 3 4 4 8 24

Fig 10

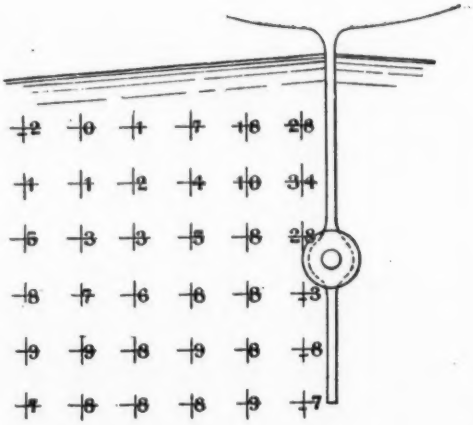

12 9 4 7 18 28
1 1 2 4 10 34
5 3 3 5 8 28
8 7 6 8 8 13
9 9 8 9 8 18
7 8 8 8 9 17

Fig. 11.

quarters. Water lines one inch apart were painted around the the stern, and thus the outline of the wave was readily plotted from the photographs. Longitudinal sections of the wave, clear of the stern, were plotted in a similar manner from photographs of its profiles on thin vertical metal plates carried by the model. These were approximately parallel to the center line of the model, but curved longitudinally to correspond with the curvature of the stream lines, so as to interfere as little as possible with the wave motion.

Special experiments were also made, at different speeds, to determine the absolute depression of the boat's stern below the still-water level.

Applying these corrections to the recorded heights of the water in the gauge glasses, the net rise in each, due to velocity, was translated into feet per second by the usual formula,

$$v = \sqrt{2gh}.$$

Although the shape of this boat presents no special features of interest, the model being that of an ordinary full-lined steamer, it may be useful to place on record some particulars of the conditions of its wake as measured by the process I have described, and I therefore show, in Figs. 3 to 7, sections of the water around the stern—longitudinally, transversely and horizontally—giving the measurements resulting from a series of runs made at a speed of 460 feet per minute.

The three transverse sections were made at distances of 3, 12 and 21 inches respectively before the rudder post, and the figures marked on those sections represent the forward speed of the wake as measured in 204 positions. The speeds are shown, for convenience, as percentages of the speed of the model, and the interval between the figures represents a distance of 4 inches. The horizontal and longitudinal sections show the inclinations assumed by some of the submerged tubes, and the stream lines which I have added appear to be consistent with those inclinations.

At first sight it may appear that the forward speeds in many portions of the wake are overstated and inconsistent, but, after repeated and captious experiment, I conclude that the figures are

accurate, and I will now attempt to show how they may be accounted for.

First, then, as regards the frictional wake. What is the maximum forward speed induced in the water by the passage through it of a surface 28 feet long in the direction of its motion, at a velocity of 460 feet per minute? How far from that surface is the water disturbed, and what are the speeds at intermediate distances from that surface?

In order to obtain information on these points I fitted measuring appliances (somewhat similar to those already described) to a flat plank, which was towed at different velocities on the surface of the water. The first series of experiments with the plank was made to ascertain the velocity of the frictional wake in contact with its surface, which was coated with black varnish. The open ends of five tubes (one of which is shown at Fig. 8) projected beneath the underside of the plank; the other ends of the tubes were connected with the gauge glasses already described.

The speeds recorded at distances of 1 foot, 7 feet, 14 feet, 21 feet, and 28 feet from the leading end were respectively 16 per cent., 37 per cent., 45 per cent., 48 per cent., and 50 per cent. of the velocity of the plank; and these proportions appear to be maintained at all speeds between 200 and 400 feet per minute, the latter being the highest speed that the arrangements would allow. Having thus determined the maximum velocity of the frictional wake, other experiments were made with this plank to show the manner in which the motion of the water in contact with the surface was gradually imparted to the layers of water lying underneath. For this purpose six tubes were arranged in a vertical row, being placed 28 feet from the leading end of the plank, and carried by fine wires, as shown on Fig. 9; the forward ends of the tubes being open, and their after ends connected to the gauge glasses. The results of experiments at 200, 300 and 400 feet per minute are also shown by Fig. 9; and it would appear that the velocity decreases in a geometrical progression as the distance from the surface increases in arithmetical progression; thus, at a distance of 28 feet from the bow end, with a quality of surface similar to that of this plank, the forward

velocity of the water in contact with that surface being 50 per cent. of the velocity of the surface, at a distance of $\frac{7}{8}$ inches away it is reduced to one-half, or 25 per cent., at $1\frac{3}{4}$ inches away to one-fourth, or $12\frac{1}{2}$ per cent., and so on; so that at a distance of about 5 or 6 inches away from the surface the water remains practically undisturbed. The retardation of velocity in the somewhat analogous conditions of orbital wave motion, of the flow of rivers, and possibly of glaciers, appears to confirm the foregoing observations as regards the ratio of decrease in velocity of the frictional wake.

An interesting mathematical investigation of the thickness of the frictional wake will be found in the Report of the British Association for 1874, where Dr. Froude points out that the new momentum W V, generated in each second in the surrounding fluid by the transit of a surface, the resisting force of which is F, must be equal to F g (g being the force of gravity, W the weight operated on in pounds, and V its velocity in feet per second). Probably some portion of the operating force F may be expended in raising the temperature of the water; but, neglecting this, and substituting the measured speed of the wake in contact with the surface, for Dr. Froude's assumption, "that it possesses a velocity equal to that of the surface," and modifying also his assumption of the intermediate gradations of speed being uniform, it is possible to calculate the velocity of the frictional wake at any distance outward from a surface of which the frictional resistance is known; and the correspondence between experiment and calculation, as applied to the cases shown at Fig. 9, is strikingly close. The frictional resistance of the model vessel, at a speed of 460 feet per minute, estimated from its resistance at lower speeds (when wave-making resistance was practically eliminated), and assuming that the resistance varied as the 1.85 power of the velocity, would be about 32 pounds. Now, if it were possible that the whole of the fractional wake could be confined within the area of the propeller disc (which in this model was 270 square inches net), and that it possessed a uniform velocity throughout that area, then its utmost velocity V, in the

equation $F\,g\,t = W\,V$, would be but 1.38 feet per second, or 18 per cent. of the speed of model.

If, with somewhat greater probability, the frictional wake, after following the curved surface of the vessel, be ultimately found at the stern flowing in vertical strips of the same depth as, and parallel to, the stern frame, the central maximum speed being 50 per cent. of the speed of model, and the speed of the outlying strips decreasing in the same ratio as in the case of the plank, then, to satisfy the equation, the total thickness, on each side, of the disturbed water would be about 8 inches; and the speed of the frictional wake in the six positions indicated by the vertical rows of figures, next the stern post, at Fig. 5, would be 25 per cent. of the speed of model, and in the next row outside 3 per cent. or 4 per cent. only.

Clearly the frictional wake is inadequate to account for the speeds shown by experiment.

Another element of wake disturbance is that due to the orbital motion of the particles of water in the stern wave raised by and moving with the vessel. There are several circumstances in connection with this wave which are not comparable with the case of a free wave, having its internal motion in accordance with the trochoidal theory; still the points of resemblance may warrant an attempt at comparison, and I would therefore refer to Fig. 7, which shows the profile of the wave in contact with the model, at a speed of 460 feet per minute, the maximum height of its crest above the still-water level being about 4 inches.

For a trochoidal wave of the same height, the orbit of the surface particles is about 7 inches in diameter; and, as the length of the wave was about 7 feet, and its velocity that of the model, or 460 feet per minute, the surface particles have an absolute forward velocity, at the crest of the wave, of 120 feet per minute, or 26 per cent. that of the model. At the level of the keel this orbital forward velocity is reduced to about 5 per cent. of the model's speed. These are the maximum velocities due to a trochoidal wave, 4 inches high. The crest of the wave, however, was not uniformly 4 inches above the still-water level, but was reduced in height as it left the vessel's side, so that at the out-

ward limit of the wake section (shown at Fig. 5), the height of the wave and the orbital forward velocities were little more than one-half the maximum. If the internal motion of this wave corresponded throughout with a trochoidal wave, then at a cross section, about 18 inches forward of its crest, the orbital motion would be simply upwards, and could not contribute in any way to the forward wake motion. It so happened that the measurements shown at Fig. 3 were made near this position, whilst the numerals on Fig. 5 show the measured velocities near the wave crest, and the influence of the wave motion can be roughly traced by a comparison of these two diagrams.

Before making any numerical comparison between the measured velocities and those deduced from the foregoing assumptions, it may be well to call attention to some of the circumstances in connection with the actual wake which are not similar to the assumed conditions, and which would necessarily show discrepancies in the results. As regards the stern wave, the orbital motion of the particles of water is probably being rapidly accelerated during the short time occupied in its formation (less than one second), whilst the trochoidal theory assumes that this motion is uniform, and also that the fluid is frictionless. Then the orbits of the trochoidal wave are circular, so that each particle returns to the crest in precisely the same position that it occupied on the preceding crest; but the frictional wake distorts this circle into a looped figure. Modifications are also introduced by the interference of other waves formed by and traveling with the vessel. It was assumed that the frictional wake would appear at the stern frame as a series of vertical strips, each having a uniform velocity from the keel to the surface of the water, and that this velocity had been communicated in consequence of such strips retaining their relative distances from the surface of the model throughout its length, notwithstanding the continuous change in its cross section. But this assumption credits the water with a mobility which it does not possess; and the inclinations assumed by the measuring tubes, such as shown at Fig. 6, appear to indicate clearly that particles of water, which at one instant are comparatively close to the vessel's side, and

are thus sharing the velocity due to such proximity, may a second later be found much further away from the vessel, there contributing their previously-acquired forward motion to the wake, in positions where no frictional motion could be found if those particles had continued to flow in directions parallel to the surface of the vessel's stern.

Being thus prepared to find discrepancies, such as may fairly be anticipated, between the measured velocities and the theoretical wake motion, so far as it is accounted for by the wave and by the friction of the model, we may now, with advantage, refer to Fig. 10, on which are plotted the velocities, abreast the screw aperture, due to the combined effect of the frictional wake and the wave motion, calculated in accordance with the assumed conditions of a trochoidal wave, and of a frictional wake moving in vertical strips. These velocities, for comparison with Fig. 5, are shown as percentages of the speed of model, and they are plotted at intervals of four inches apart.

The deficiency in velocity, not accounted for by the supposed conditions, is shown at Fig. 11, being the differences between the numerals on Fig. 5 and Fig. 10; and, although in some of the positions the differences will not, perhaps, be thought very great (about one-third of the actual measurements differing not more than 5 per cent.), still the majority of the measurements are in excess, and in many of the positions they are considerably in excess of the velocities accounted for at Fig. 10.

This unexplained excess in velocity appears to indicate the influence of some source of disturbance beyond those already discussed, and I think it is not unreasonable to conclude that the residuary velocities shown at Fig. 11 are really owing to what has been denominated "dead water." The term, however, in this connection is somewhat misleading. Instead of a large volume of water accompanying the vessel inertly (as "dead water" is assumed to do), no measurement recorded a forward speed more than 67 per cent. of the speed of the model, including the velocity due to all causes. This speed, however, was measured at a distance of two inches from the center line, and it seems probable that immediately behind the stern post a velocity of 100 per cent. might have been found.

Dead water has been described as constituting the conditions of established motion belonging to the ship, the conditions differing in the principles of their constitution from the frictional wake, inasmuch as, when once established, they no longer expressed any elements of which the ship's resistance consisted, since they had been established once for all.

As any mechanical measurement of the wake currents must necessarily take account of the total velocity, derived from whatever source, and as it is only after the frictional and wave elements have been eliminated that the extent of the dead-water influence is apparent, I have reserved the consideration of this element of wake motion until some conclusions could be formed respecting the others.

It is significant that those positions in which the unexplained forward velocities are highest are just those portions of the wake where the existence of some obstacle, preventing the particles of water from following the contour of the vessel, appears to be indicated by the direction of the stream lines outside (see Fig. 6), this obstacle being, apparently, a more or less permanent fluid addition to the stern, as if an attempt were being made, so to speak, by the water to effect an improvement in the ship's lines in order to allow the streams outside to flow past in their natural courses. These courses, as shown at Fig. 6, may perhaps suggest the extent to which it would be necessary to fine the model's stern, if, at the experimental velocity, the forward speed of the wake were to be confined to frictional and wave motion only.

But if those particles of water which have been near to, or in contact with, the vessel for the greater part of her length are thus abruptly diverted from the vessel's surface on their nearing the stern, so as to escape past the dead water, then our supposition that the frictional wake appears at the stern post in the form of vertical strips is no longer tenable, and we must now credit the dead water with a greater forward speed in the upper central portions of the wake than that shown at Fig. 11, because its velocity there has not been augmented by the frictional wake, as was supposed.

Again, in apportioning the frictional wake (see page 875), none

of its velocity was allotted to any position lying more than six inches from the center line; but, if the streams are split away from the vessel's stern, and the particles of water, with their acquired forward motion are now really to be found at some distance from the center, then the excess of velocity in the outlying portions of Fig. 11 must really be credited to the frictional wake, whilst the velocities in the upper central portions, specially representing the dead-water element, are really shown too low, by the amount that was erroneously apportioned as frictional wake to those positions.

The body of water included in these measurements had a breadth equal to the extreme breadth of the model and a depth equal to her draught. The mean forward velocity of this water, measured abreast the screw aperture, was 19 per cent.: of this 5 per cent. has been shown to be due to the frictional wake, 9 per cent. to wave motion, and the remaining 5 per cent. has been credited to the influence of "dead water," and I submit that the various speeds shown at Fig. 5 have been thus approximately accounted for.

But it must be admitted that the attempt to explain circumstantially all the phenomena shown by these experiments has not been completely successful, and there are some apparently anomalous results which do not appear to fit in with the suppositions introduced. To this extent any calculations and predictions as to the wake of a vessel, apart from experiment, will be liable to error and should be verified by actual measurement with model or ship.

As regards the total value of the frictional wake, there is, perhaps, little chance of mistake, as our knowledge of frictional resistance (due principally to Dr. Froude's researches) is fairly complete, and the connection between that form of resistance and wake motion is based on "the universal law connecting force and momentum." The analysis of the confused internal motion of a wave in course of formation is much less satisfactory, there being nothing to guide us except a profile of its surface. That the "dead water" of model and of ship will be similar at "corresponding speeds" is an assumption based on the stream-line the-

ory, and although observations of the correspondence between the model ship's waves and the full-sized ship's waves have verified predictions made in accordance with that theory, as regards the dead water the assumption requires practical confirmation. Still there should be little fear of error in applying the model wake speeds to the ship, provided the necessary corrections are applied for the variation in frictional resistance in terms of the variation in the length of surface.

With these remarks on the connection between the wake of model and wake of ship I will conclude this paper, reserving for some future occasion a description of the modifications in the wake motion which resulted from the rotation of the propeller blades, and a discussion of the nature and causes of "augmentation." The diagrams I have given are probably the first record of grouped local measurements of the wake, and, although they show but one set of observations at one speed, and refer, strictly speaking, to the condition of the water around one small vessel, I hope they may be found a useful contribution to our limited stock of information respecting the phenomena which, in the aggregate, constitute the wake currents.

THE MOTIVE POWER OF SMALL VESSELS.

[Reprinted from "The Engineer."]

For vessels larger than canal barges there is but one method of obtaining the necessary propulsive power other than by sails or horses, and that is by the use of steam. Considering that steam was so employed in the early days of the century, and will certainly be so used at the end of it, the advance that we are constantly being told has been made in science, etc., is not so very apparent or striking. For vessels not exceeding a canal barge in size or an omnibus in speed, three other methods of obtaining the necessary power have, during the last couple of years, been developed to a considerable degree of perfection, and for many purposes are preferable to steam. These methods are: The evaporation of a volatile liquid, such as naphtha; the generation of and explosion of gas and air; and the electrical energy contained in secondary batteries. Steam, naphtha, petroleum and electricity have each their own particular sphere of usefulness, and, speaking generally, the conditions of each case will indicate the kind of motor to be employed. When, however, a trader is informed that a launch intended for service on a creek in West Africa will be more cheaply propelled by means of secondary cells, a brief description of the principal features of each motor seems desirable.

In deciding upon the kind of motor to be employed in a small vessel, the chief points to consider are, the speed required, the weight of the motor, the consumption of fuel and the space occupied by machinery and fuel; other considerations are the cost of providing the energy, degree of skill required in handling the machinery, effective distance, or what is the same thing, the maximum energy endurance. Another and equally important matter is the degree of that indefinite quality known as seaworthiness. The relative importance of these points will largely

depend upon the purpose for which the vessel is intended, whether for river or harbor service, whether for business or pleasure; it is safe to conclude that that motor is the best which gives the greatest power with the least weight, and for the least expense in prime cost and maintenance. Steam launches are such familiar objects that little need be said about them. What renders the steam engine so superior, or rather so preferable to other motors, is the possession of certain qualities which are, at any rate for purposes other than pleasure, a necessity. Thus there is a fairly regular turning moment acting on the shaft; in the compound engine the turning moment is practically constant; the speed of the engines can be varied at will; the expansion, and therefore the power to be developed, can also be varied; while the engine is, so far as direction of rotation is concerned, reversible. For these reasons the steam motor is likely to hold its own even in small craft, for some considerable time, as these advantages are, in the opinion of many people, considered to outweigh its low efficiency. For very small craft two simple engines are usually employed, but compound, and even tri-compound engines with condensers, and forced draft for the boilers, etc., are used in the larger and faster class, where the power is up to 150 I.H.P., and the speed 14 or 15 knots.

The engines for launches have partaken in the improvement in details that characterizes the modern marine engines, with the result of considerably reducing the weight. The use of steam at high pressure permits the employment of a smaller boiler, and this means more bunker capacity. In small-powered launches the total weight of the engines, boilers and all machinery, should not exceed 160 pounds per indicated horse power; indeed, it can be made much less. As an example, a 30-foot launch, with a speed of $7\frac{1}{2}$ or 8 knots, will require machinery developing 18 indicated horse power, and which will weigh 170 pounds per indicated horse power; such a boat will run for twelve hours with 6 cwt. of coal. A 50-foot launch, with a speed of $11\frac{1}{2}$ to 12 knots, will require engines developing 85 to 90 indicated horse power; she will run for twelve hours with $1\frac{1}{2}$ tons of coal. For work on exposed rivers and harbors this latter boat is all that can be de-

sired. For surveying, submarine mining, conducting explorations, &c., a boat of this type is extremely useful, as by the use of a smaller speed a large reserve of power is kept in hand, with a corresponding increase in the effective distance that can be steamed.

Steam launches, or rather steam engines, are so extremely useful, especially abroad, owing to their very catholic taste for fuel. Anything which can burn can be thrust into a furnace of a boiler; the only thing is to see that the quantity of fuel varies inversely with its calorific value. Thus, rice, grass, mats, cotton, wood, &c., can on occasions usefully replace coal, especially when the latter may be £2 or £3 per ton, and of bad quality at that, while in places where petroleum is plentiful an intelligent mechanic can easily fit an injector and brick up the furnaces.

The disadvantages of steam motors are principally those resulting from the absence of skilled attention. As a general rule, it may be said that the higher the pressure employed the greater the necessity for the employment of a properly qualified engineer. This means paying a good deal for wages. It is surprising how very rapidly the boilers of small craft deteriorate. This is especially the case where the boat is laid up during the winter. Though during such periods they receive little or no attention, that would avoid the necessity for the costly spring overhaul that owners of these craft are accustomed to pay for. The boiler is left for months or weeks unprotected, water is usually left in it, and usually a manhole door is left off; corrosion inside is thereby hastened. In the furnace is left an accumulation of ashes, which gets wet and does its part in hastening corrosion. Underneath the boiler the bilge water does its share, and thus surrounded inside and out with damp air, the plates quickly oxidize. It usually costs a good deal to maintain a steam launch in good working order.

Just as the gas engine replaced the small-powered steam engine, so is the petroleum motor superseding the former. Gas engines are of course impossible for marine purposes, but the petroleum motor is, at any rate for small powers, very suitable, and where there is a cheap and plentiful supply of petroleum it

is bound to replace steam. Petroleum motors have so often been the subject of scientific research, that any detailed description is unnecessary. There are several kinds in the market, but perhaps the Priestman and the Capitaine are the best known. So far, the petroleum motor is essentially a modified Otto gas engine; the cycle of operations and the principle of working being the same; that is to say, it embodies the features, good and bad, of that motor. The great advantage of a petroleum motor is that it is self-contained. No boiler is required, and its limit of effective distance is regulated solely by the capacity of the storage tank. It requires the minimum amount of attention. There are no sparks or smoke, the space occupied is but that of an ordinary steam engine of the same power. The storage tank can conveniently be placed either as a shallow 'midships tank or else in the bow chamber.

Petroleum motors working on the Otto cycle labor under two disadvantages, which, at any rate for naval purposes, render them unsuitable. These are the constant speed and constant direction of rotation. In other words, the motor is, when working, running at full speed and in one direction only. Of course, it would not be at all difficult to devise mechanical means whereby the speed of the propeller shaft could be varied, while that of the engine remained constant. But this would involve a rather complicated gearing, and would occupy considerable space and weight, and would also absorb power. The second disadvantage is surmounted by the employment of the familiar bevel and friction gear. This enables the propeller shaft to stop or rotate ahead or astern without altering or stopping the engine in any way. McGlasson's reversible propeller solves the difficulty in another way. For small launches, when the power transmitted is but low, and where the speed of the vessel does not require to be adjusted, these methods of stopping and reversing are quite permissible; but in such operations as dropping or creeping for a mine, &c., in a tideway, the speed of the boat has to be varied from time to time, and it is the facility with which this can be done in a steam launch which makes steam so preferable. Another disadvantage of the Otto cycle is that there is but one impulse

in every two revolutions. To make the petroleum motor suitable for marine purposes it is necessary to place two engines side by side; this provides an impulse at every revolution, and by the means of a fly-wheel the angular velocity is maintained practicably constant. The weight of petroleum motors may be taken at 300 pounds per indicated horse power, but for the larger sizes it is somewhat less.

The naphtha motor is in many respects superior either to the steam or petroleum engine. It possesses all or nearly all the advantages of the former without the disadvantages of the latter. It is much more extensively employed in America and in Europe than in this country. The great disadvantage attaching to this motor is that it employs a highly volatile and inflammable liquid. So long as glands, joints and valves remain tight, there is no danger whatever. Leakage has, however, to be most carefully guarded against, and while a blowing steam gland indicates merely a degree of carelessness, a blowing naphtha gland may be the cause of an explosion. The cycle of operations is precisely similar to those of a steam engine, and like the latter, a naphtha motor can be started in either direction, stopped or speed graduated with equal facility. As regards weight, the naphtha motor is the lightest of any and occupies the least space. The weight for the small powers usually employed is about 135 pounds per indicated horse power. These naphtha launches are very suitable for yachts and pleasure purposes, as they are clean, light and easily handled. Any light spirit can be used. Naphtha, gasoline, benzoline, &c., are, however, liquids which require great care in handling and in transporting, and cannot be purchased in every place except in very small quantities. These liquids have a very low flash point, and this makes them distinctly inferior to petroleum as a fuel. As made by such firms as Yarrow, the naphtha launch has, by the superior workmanship employed, many of its risks eliminated. If the manufacture of this motor was the subject of competition, the inevitable cheapness would result in considerable danger to ignorant or unskillful users. Naphtha and petroleum motors are liable to become offensive in the eyes of fastiduous people by the smell they emit when a bad oil is used

or the combustion is not perfect. It may be said that it is better to use a pure spirit and a high grade oil rather than the cheaper kinds.

Much, very much, is said in the press occasionally about the advantages of electricity as the motive power for launches, etc. Enthusiastic persons talk and write about an electric torpedo boat. There is something which appeals very strongly to the imagination in the idea of a boat urged along at a high speed, making no noise, emitting neither sparks, nor smoke, nor smell, to indicate its whereabouts. That a torpedo boat which would do this would be an acquisition to any, now goes without saying. Another class of people advocate the use of electric launches for war ships and mail steamers. They urge that while the dynamos are lying idle in the day-time, they might usefully be employed in charging the cells of the electric launch. All this enthusiasm proceeds from the performances of certain small river craft which are propelled by electricity. Visitors to the upper Thames have often been impressed by the neat, clean, swift, comfortable launches which are now fast replacing the noxious steamboat.

As a means of converting electrical energy into mechanical work, an electric motor is practically a perfect machine. Could we stow the electrical energy in receptacles one-tenth the size and weight of the present storage cells, and did the operation take about one-tenth of the time now occupied, there would be no need to discuss the most suitable motor. At present the use of electric motors and secondary cells is attended with considerable disadvantages, which have the effect of limiting their field of usefulness to merely pleasure purposes. The motor itself is easily controlled, and its direction of rotation altered by merely shifting the brushes. Its weight is roughly about 40 pounds per horse power. The difficulty is with the cells; these are in their present form very weighty, and seriously limit the margin of useful displacement of the boat. They also occupy very considerable space. For speeds of about 6 to 7 knots, and for an effective endurance of about six hours, batteries are useful enough; indeed this method of propulsion is, perhaps, the best. All the

weights being low down, the boat is very stiff, and when "youth is at the prow and pleasure at the helm" this is a distinct advantage. For open harbor work, ship work or naval purposes, the electric launch is wholly unsuitable. For such work we require at least a speed of 7 knots and an endurance for twelve hours. If we obtain this by means of cells, it means an enormous weight. Thus the 30-foot cutter requires an engine indicating about 18 horse power to drive it at 7½ knots. The weight of the engine and fuel for twelve hours is about 1.75 tons, or about 220 pounds per indicated horse power. To obtain this power from a battery would mean a weight of cells and motor amounting to about 15½ tons, or more than twice the load displacement of the boat. If we bear in mind that this gives about 1,800 pounds per indicated horse power, and that the resistance to propulsion varies approximately as the square of the speed, and that the power necessary to overcome this resistance varies as the cube of the speed, it is easily seen that the limit of useful employment of secondary cells is quickly reached. For sea and harbor service there would be endless difficulties connected with the plates, spilling acid, irregular charging, &c. The electric launch is, in fact, a toy.

A point worth consideration in the motors we are discussing is the time taken for the power to be developed. If we are using secondary cells, these will require a period of six to ten hours for charging, so that a launch thus fitted is available for service only for fourteen or eighteen hours per day, that is, for continuous running during that time. A steam launch is compulsorily idle only for the time requisite for cleaning fires, bunkering, etc.; practically she is always available. Petroleum and naphtha motors are only idle during the time necessary to fill the tank. Petroleum motors require some few minutes to start from the cold state.

As regards the fuel supply and cost, it may be said that this important item depends so much upon local considerations that no rule can be laid down, and the most economical motor will be that which costs the least for energy. The cost for one horse-power for twelve hours is roughly about 7d. in the case of bat-

teries, that is for current only, 6½d. in the case of petroleum motors for oil only, and less than 3d. for coal in steam engines. The price of naphtha is dependent upon the locality, and where it has to be conveyed any distance it is, as an "inflammable substance," liable to extra charges.

It is often urged that the great advantage of naphtha, petroleum, and electro-motors is that they require no skilled attention. This is no doubt true so long as no hitch occurs, and the man in charge is not particularly unintelligent. When, however, something goes wrong, skilled attention is requisite, and the user then finds that he pays the maker, or repairer, for the commodity. It may be laid down as a general principle that all machinery, whether it be a domestic wringer or a torpedo, requires at least intelligent handling if it is to be run with economy and with absence of expense for repairs. Those who may, then, be debating the question of naphtha, or petroleum, or batteries, or steam, will do well to remember that an intelligent appreciation of the science of each will be an important factor in determining the relative expense of each method of working. In places where steam launches are used an engine attendant can be had for little higher wages than an unskilled laborer; the same man, if moderately intelligent, will quickly master the *rationale* of a petroleum or naphtha motor; but to look after a battery of secondary cells, requires, if not skilled attention, at least considerable technical knowledge. From the point of view of safety the best motor is undoubtedly the petroleum engine. In the case of a naphtha motor a leaky gland or joint might possibly produce an explosion. In the case of a steam boiler, unchecked incrustation, or shortness of water, might result in an explosion, and would in any case mean heavy repairs. While in the case of secondary batteries, buckled plates, a too rapid discharge, reversals, etc., are vexatious and expensive troubles, although not dangerous to life. Such, then, are some of the principal points to be considered in the choice of a motor for small craft.

MARINE BOILER CONSTRUCTION.

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[Paper read before the International Maritime Congress, London Meeting.]

In responding to the request to contribute a paper on some subject connected with marine engineering, it was felt by the author that, as his work on boilers is on the point of being published, and as his time has only recently been much occupied in considering the numerous problems connected with their construction, it might be possible to place before this Congress both a concise and yet a fairly exhaustive summary of the present process of manufacture. That these few remarks cannot claim to be more than a very brief outline will, it is hoped, soon be apparent; but that the field is also a very much larger one than would at first sight appear, will become evident on recalling the various subjects connected with it, and which affect either the sizes or the processes of manufacture.

There are all the various conditions of working a boiler at sea, the question of coal consumption, leakage and corrosion, the efficiency, heat transmission, funnel drafts and priming. All these are important matters, and may not be neglected in determining the sizes of boilers. As regards scantlings, it is also necessary to know how steel behaves after being under the various treatments to which it is subjected in the boiler yard as well as at sea, to what extent heat affects it, what injuries punching and drilling will produce, and what are the various causes of spontaneous or mysterious cracks and failures.

But when all these matters have been satisfactorily ascertained, there remains the as yet practically unexplored field of stresses in boilers. The problems seem simple enough—given a cylindrical shell, a cylindrical furnace, a screwed stay or a flat plate,

find what pressure any one part will stand without giving way. But if these questions are examined carefully, the simplest of them grows complicated. Thus screwed stays of 1 square inch section might be expected to withstand a pull of from 25 to 30 tons, yet in a boiler they sometimes break before apparently 10 tons is reached. This is most probably due to a combination of tension and bending stresses, caused by the relative change of form of the boiler shell and of the combustion chambers, but which is not easily determined. If this uncertainty did not exist, if one could accurately calculate the strength of the various parts of a boiler, then there would be no need for the present high factor of safety.

On account of the extensiveness of the general subject, the following remarks will be restricted to a description of the various workshop practices, though to do this without very numerous illustrations must naturally be a difficult and not altogether satisfactory task.

On receipt of the steel plates at the boiler yard they are measured, and then marked off, ready for planing the edges and for drilling the holes. Sometimes the holes in the shell plates are drilled before the edges are planed, sometimes afterwards, and in shops fitted with the newest appliances, the holes are not drilled until the shell plates have been bent and bolted together. This plan is recommended as being the best, but it is slower than drilling the plates before bending, because otherwise the drilling of the holes cannot be commenced until the planing and bending is completed, whereas in the other case the two operations end together. Besides, on account of the possibility of using multiple drills, this part of the work is so much accelerated, that in some shops all holes are drilled before bending the plates, and are subsequently enlarged when the plates have been bolted together. Finally, these should be separated and the burrs removed, in order that none of them may lodge between the plates, thus preventing them from coming into close contact.

The drilling of the shell plate holes naturally takes up more time than the drilling through the thinner plates in the interior of the boiler, not only because these holes are fewer and smaller,

but also because more drills can be employed at one and the same time. On account of the proximity of flanges, and because of irregularities in the shape of most of these seams, the slower process of hand drilling is still indulged in in many works, only a few having supplied themselves with the necessary special drilling machines.

After being planed on their edges, and either before or after drilling, the shell plates are bent by passing them through a system of three rolls which are placed either horizontally or vertically. The operation is very simple, but, for obvious reasons, the ends of every plate that passes through these rolls cannot have been bent to same curvature as the rest of the plate, and require to be set by other means. Numerous attempts have been made to arrange three, four, and even five rolls in such a manner that this additional work is not necessary, and presses have also been used for this purpose; but the results are not satisfactory, and the plan now usually adopted is either to leave the plates longer than required, and finally cut off the two ends and use them as butt straps, to heat the ends of the plates before rolling and to hammer them to the proper shape, to press them into shape after rolling between the jaws of a riveting machine, or even to leave them flat and to spring them with the help of the two butt straps with which they are covered. Where lap joints are used, the difficulty is still greater, because the curvature of one plate is reversed, and this change is a very sudden one. In some works long iron heaters are placed along this line, and the projecting lap hammered down.

To those engineers who have studied the failures of the last ten years, such a treatment at once suggests that it may seriously endanger the strength of the structure, and a few remarks on the injury done to steel by working it at a certain temperature, called either blue heat or black heat, may be of interest, or rather the following simple experiments will show what the danger is.

Strips of mild steel $1\frac{1}{2}$ inches thick and 1 inch or 2 inches wide are sheared about 6 inches or 9 inches long. Of these No. 1 is placed half way under a steam hammer or press, and its pro-

jecting end bent down with a sledge hammer through an angle of 45 degrees. The steam hammer is then lifted, and the bent part of the angle placed uppermost and again hammered down. According to the toughness of the steel, this operation can be repeated from ten to thirty times before the sample breaks.

No. 2 is placed between two bars of iron which have been heated to a dull redness, and is kept there until the bright sheared edges have changed their color to a straw or purple one. This sample is now treated in exactly the same way as No. 1, but it will break after one or two bends. If it had been heated till it had grown dark blue or even gray, it would have stood as many if not more bends than No. 1. This shows that there is a critical temperature at which steel or iron is rotten.

No. 3 is treated in exactly the same way as No. 2, with this difference, that the bending is stopped as soon as a surface crack shows itself. It should be put aside for a day, and can then be broken by simply throwing it on an anvil or striking it with a hand hammer. This shows that by this special treatment steel and iron can be made permanently brittle. This brittleness is removed by annealing, but not by long-continued rest. It can be produced by any mechanical treatment if carried out at a blue heat, and it is not necessary that surface cracks should show themselves; this is only recommended as a guide to insure a successful experiment.

Applying this lesson to the above-mentioned case of bending a shell plate near the end of its lap at a blue heat, it is but too probable that it will account for many failures at this point—that is, an inch or two inside of the inner row of rivets.

Heaters are also very frequently applied to furnace mouths and saddles, and it is these parts more than any other which fail by cracking after being in use for some time. Fortunately, this never occurs under steam, but afterwards when the boilers have cooled down.

It would, however, be rash to assume that all such failures are due to injurious treatment in boiler shops; for there is only too much ground for believing that the temperature of boiler plates when steaming often reaches a blue heat, particularly

under forced draft; and where this is combined with a concertina action of the various corners, brittleness of material and subsequent cracks may be expected.

Some of these remarks apply to the treatment of internal parts of boilers, but before discussing them a few remarks on riveting the shell seams are necessary.

A riveted joint should be both strong and watertight; whether this is so or not depends not only on the design, but also on the workmanship, whether the holes are fair, whether the plates are in close contact, and whether the rivets fill the holes. To attain these various objects the plates should not only be well fitted, but during the riveting operation they should be firmly screwed together by numerous bolts, and the pressure of the hydraulic riveter should not be removed until the rivet is fairly cool, otherwise the remaining spring of the plate tends to stretch it, thereby reducing its diameter and also allowing the seam to open.

The usual plan of riveting boiler shells is to do all the longitudinal seams first and then the circumferential ones, starting at the back end seam. But then, unless the front plate is flanged outwards, its seam has to be riveted by hand. In a few works special hydraulic riveters or special steam-hammer riveters do this work.

The following are some of the troubles and dangers to be expected with riveted seams: Leakages frequently show themselves at the ends of the longitudinal butt-strapped joints, and up to the present the only really effective means of preventing this is to plane or draw out the ends of the outer butt straps of the inner strakes, and to tuck them in under the adjoining strakes. It is customary either to drive steel wedges into the butts of the outside strakes or to substitute screwed plugs for the rivets which pass through their center lines. These studs or plugs are also often used instead of rivets in various difficult corners in the combustion chambers and elsewhere. In some works such corners and the ends of troublesome seams are welded. One danger which attends hydraulic riveting is, that if too much pressure is applied, or if it is applied too suddenly, it may lead to the im-

mediate or subsequent bursting of a riveted seam, so that manufacturers who can boast of the heaviest riveting machines, unless they use them judiciously, may be doing more harm than good. Indications of excessive pressure having been applied to the rivets can be detected by the undulatory shape of the originally straight edges of the various riveted seams.

During the period that the shell plates of a boiler have been planed, bent, drilled, riveted and caulked, the plates of the internal parts will have been flanged and fitted together, drilled, riveted and caulked ready to go into place.

To describe the flanging operations in detail would require far too much time, and therefore only a very short summary can be attempted. The edge of the plate to be flanged is heated to redness, about 2 feet to 4 feet at a time for hand flanging and 6 feet to 8 feet for machine flanging, the length depending somewhat on the thickness of the plate, the thinner ones growing cold sooner than the thick ones. The plate is placed on iron blocks with the heated edge projecting, which is then bent down either by an hydraulic press, a steam hammer, or by heavy wooden mallets. Hand flanging is impracticable for plates above 1 inch in thickness, but as regards accuracy of work all three processes are about equal.

Like the other operation, flanging is also not without its dangers. Burning and wasting away and undesirable deformation may be guarded against, but, in spite of the very greatest care, plates which have been flanged and laid aside are sometimes found to have cracked overnight. Annealing a plate immediately after flanging is not always practicable, and in order to relieve it of its severest strains some smiths have adopted the plan of heating the center of every plate immediately after flanging. It is also affirmed that only such plates have cracked as were kept carefully flat during flanging, whereas the puckered ones escaped uninjured.

Why plates should crack spontaneously in this manner is as yet a mystery; for although there can be no doubt that one of the causes is the slowly increasing strain on the unflanged end during the period that the flanges are cooling, still it seems un-

reasonable that a material which will elongate 20 per cent. in a testing machine and show a silky fracture, should tear asunder when worked into a flanged plate, and then reveal a coarse structure. To attribute these failures to incipient flaws, which was at one time a favorite explanation, is nowadays not considered a satisfactory one. The only other one which suggests itself is, that the slowness with which the stresses grow in the circumference of the plate destroys its ductility and increases its hardness to such an extent, that certain zones may have become brittle. At any rate, it is well known that the elongation diminishes and the tenacity increases the slower a steel test piece is broken. If torn asunder by a dynamite explosion, a test piece elongates about twice as much as under ordinary circumstances.

There is nothing particularly strange in the fact that such fractures sometimes extend right across a plate, for it must be remembered that the metal on either side of a fracture is at first moving at a velocity equal to that with which sound travels on steel, viz., three miles per second, or about five times faster than a rifle bullet.

Another trouble connected with flanging, is that due to the very serious change of form of all flanged plates after annealing; various means had to be adopted to prevent it, for otherwise furnace holes would invariably be at least 1 inch oval. This is also one of the chief reasons why it is practically impossible to anneal plates after they have been fitted, unless they are kept bolted together while in the furnace. That sufficient allowance (usually $\frac{1}{8}$ inch) is rarely made for end plates where they have been heated for fitting together, can be demonstrated on nearly every boiler, the shell plates at these points generally showing a slight depression where they have been made to follow the retreating material of the corners. Similar remarks apply to the flanged plates of the combustion chambers.

The flanging of furnace saddles is one of the most difficult operations in the boiler yard. Recently, on account of numerous failures, much attention has been directed to this point, and the corners, which at one time were made almost square, are now only bent to the gentlest possible curves. This is effected

either by arranging for the saddle seam to be on the water side of the tubeplate, or by making the flanges deeper. It is thought that the cause of the cracking of these flanges is due to working them at a blue heat, which has already been explained, to the injudicious use of heaters during construction, or to over-heating combined with local straining while in use at sea.

All such riveted boiler-seams as are exposed to the direct action of the flame, are liable to crack on account of overheating, for not only are there two thicknesses of metal, but these are separated by two layers of iron scale, and, perhaps, by an air space, or by spongy charred oil which was used for drilling, and then not removed. As every one of these substances is a very effective non-conductor, no pains should be spared in removing them and bringing the two plates into metallic contact. With this end in view, some works bore out the combustion chamber front plate, and machine the back end of the furnace; others pickle the plates so as to remove the scale, and others, again, wash the seams with sal-ammoniac, but none of these means will be efficient unless the very greatest care is taken during the riveting operation to draw the two plates quite close together by numerous bolts. As the difference of the diameters between the furnace and the hole into which it has to fit is often more that $\frac{1}{4}$ inch, it is evident that the plates cannot be brought into contact unless they are stretched, either by being very heavily hammered if cold, or screwed up if warmed with heaters. That there is danger in both methods has already been mentioned, but in practice it seems that failures need not be apprehended if the plates are heated beyond a blue heat.

The riveting of the internal parts presents no special difficulties and is chiefly done by hand.

Caulking is the final operation to which the plates are subjected and calls for few remarks. It is customary to caulk all boiler seams both inside and out, and apparently this is necessary, for experience seems to show that if only the outside edges of the seams are caulked, they very often give trouble while under steam, and the general idea prevails that those seams are the most perfect into which no water can enter. But it only requires

the most cursory attention to the caulking operations to be convinced that a seam cannot be depended upon for watertightness unless it has been caulked with the water pressure on it, and this is, of course, impossible with the inner edges. To caulk them for the sake of making them watertight would therefore appear unnecessary. But if the two plates are not in perfect contact, and if there is any chance of their rocking on each other during the various changes of pressure and temperature, it is evident that under certain unfavorable conditions the outside edge may open and leak, and to guard against this rocking it is necessary to caulk, or at least fuller all the inside edges, so that even those joints in which the plates are not in contact will be firmly resting at least on their two edges while the rivets are holding them together.

The final caulking operation proceeds while the hydraulic pressure is being slowly raised until double the working pressure is reached. The necessity for this high test has been repeatedly disputed, but many instances could be mentioned of boilers which failed only just before this pressure was reached, or which have exploded under steam pressure after having been only recently tested with cold water; and until such cases can be reasonably explained as being due to other causes than treacherousness of material, or ignorance of the actual stresses at the points of fracture, the general public, at least, will prefer to be assured that their boilers have been subjected to a severe proof test, and have shown themselves to be safe under conditions which are not likely to recur while they are under their care.

PARSONS' STEAM TURBINE.

[Abridged from "Engineering."]

The electric-light station at Cambridge (England), has been fitted with alternating-current machines driven by Parsons' Steam Turbines. Each plant for the output of 120 units is entirely independent of the others, and consists of a compound steam turbine arranged for multiple expansion from the boiler pressure down to a condenser pressure of 1 pound absolute, or a range of about 150-fold expansion. The motor revolves at 4,800 revolutions per minute, and is coupled direct to a two-poled alternator giving 60 ampères at 2,000 volts, with a periodicity of 80 per second, and to the same shaft is coupled the exciter; the whole plant is self-contained, and stands on rubber blocks without holding-down bolts. An automatic variable cut-off valve gear and governor enables the full range of expansion to be maintained at light loads, and secures an exceptional economy of fuel on the all-day load; the electrical efficiency of the dynamo is 97½ per cent., and the steam consumptions are recorded in the report by Professor Ewing, which we print below.

This Cambridge station is the first installation of steam turbines of the improved condensing type. They were not adopted until exhaustive experiments had been made of their performance at different loads by Professor Ewing, F. R. S., Professor of Engineering to the University of Cambridge, and from the report which we reprint it appears that instead of the turbines being, as was generally supposed, wasteful in steam, they are actually superior in this respect to most engines, and at the light loads, which are the rule in central stations, they work with a remarkable degree of economy.

Superheated steam, which was tried by Penn and others in the days of low-pressure engines, and eventually abandoned on account of the difficulties of internal lubrication of the engine, is

now being adopted by Mr. Parsons for his steam turbines. In these there is no internal lubrication, and the superheated steam has no deteriorating action, while dry steam and freedom from water of condensation appear to have a decidedly beneficial effect on the economy of the turbine, though from a different cause than that which produces a corresponding economy in the reciprocating engine. Gaseous steam moves with less friction than a mixture of gas and water over the surfaces of the blades and discs.

The only previous exhaustive trial of the efficiency of the steam turbine, with which we are acquainted, was that conducted by the jury of the Newcastle-on-Tyne Exhibition in 1888, and the result was a consumption of about 60 pounds of steam per electrical horse power. Professor Ewing's report shows that this has been reduced to one-third, or 20.1 pounds per electrical horse power, and that apparently this figure is capable of being still further improved upon, which seems, indeed, reasonable, considering the short time that the turbine engine has been under development.

Apart from considerations of steam consumption, we have on several occasions remarked on the simplicity of a turbine directly coupled to a dynamo, which it drives at the same speed, all parts being perfectly balanced; the only force is that of gravity, and the bearings being of ample area and bathed in oil, wear and tear seem to be reduced to a minimum.

REPORT ON TRIALS OF PARSONS' CONDENSING STEAM TURBINE, USING SUPERHEATED STEAM.—BY PROFESSOR EWING.

In December last (1891) I carried out a series of trials of Mr. C. A. Parsons' new condensing steam turbine, to determine the consumption of steam under various grades of output. The machine tested was a steam turbine combined with an alternate current dynamo, capable of an output at the rate of 100 kilowatts, or 100 Board of Trade units of electrical energy per hour. It was then found that the consumption of steam was 37 pounds per electrical unit when the machine was running under its full load of 100 units per hour, 39 pounds per unit when the load

was 50 units per hour, or one-half of the full value, and 43 pounds per unit when the load was reduced to one-third of its full value.

I have now to report the results of a further series of trials, made during the present month, with the object of testing how far the efficiency has been improved by certain recent changes and by the use of superheated steam. The same turbine was used in these as in the former trials, but some additional rings of turbine blades were inserted at the high-pressure end to enable it to deal more effectively with pressures up to 115 pounds per square inch (absolute), the vacuum was improved by the use of a larger air pump and by admitting the injection water at a point of the exhaust pipe closer to the turbine, and there was a new governor. The chief factor in the improvement which has now been brought about is, however, the use of moderately superheated steam. The improvement demonstrated by these new trials is very marked. Thus, in the present turbine, with steam superheated 60 degrees Fahrenheit above the temperature of saturation, the gross amount of feed water is 28.4 pounds per electrical unit generated when the machine is working at full load, and 32 pounds per unit at half load. By carrying the superheating further (to 123 degrees Fahrenheit above saturation), the consumption at full load is reduced to 27 pounds per electrical unit. Comparing these figures with those of the former trial, it will be seen that the consumption of steam has been reduced by about 27 per cent. What makes these results specially important is the consideration that there is nothing in the construction or working of the turbine to make it likely that the use of superheated steam will be attended by any drawbacks such as have been experienced in engines of the ordinary type. The steam works without lubrication, it comes into contact with no rubbing surfaces, and there is no packing to be injured.

A general view of the plant tested is given in elevation in Fig. 5 and in plan in Fig. 6. The turbine case *aa* contains a series of seven revolving discs, from the surface of which the turbine blades project. They are arranged on each disc in a series of concentric rings. The fixed guide blades stand in spaces be-

tween these rings, being carried by annular discs which are fixed to the case. Thus each revolving disc, with its neighboring fixed disc, forms a series of outward-flow turbines, the steam entering the series inside the smallest ring of blades and escaping at the circumference into a channel, which conducts it between the back of the revolving disc and of the next fixed disc to the inside of the next series of rings. The arrangement will be understood by reference to Fig. 7, which is a section showing the first three turbine discs. The heights and apertures of the turbine blades on each disc are adapted to the increasing volume of the steam as it expands from an absolute pressure of 115 pounds per square inch to an absolute pressure of 1 pound per square inch. The first six discs, which are each 15 inches in diameter, are designed to expand the steam to about atmospheric pressure, the remainder of the expansion being performed in passing the seventh disc, which is $26\frac{3}{4}$ inches in diameter, and has (unlike the other six) a double series of rings of blades, one series on each side, through which the steam flows "in parallel." The height to which the turbine blades project above the discs in which they are secured varies from $\frac{3}{16}$ inch to 1 inch. The whole number of rings of moving blades in the machine tested was 35. The blades are made of strong sheet brass, and show no sign of wear after continued use. Steam enters the turbine case at one end through a double-beat valve, shown in Fig. 7, and after passing the successive turbine discs, is discharged at *b* (Fig. 5) to a condenser. The longitudinal pressure on the turbine shaft, due to the one-sided character of the six smaller turbine discs, is balanced at the high-pressure end by a revolving baffle piston (Fig. 7), with a number of deep grooves on its circumference, which are entered by corresponding projections on a fixed bush resembling a thrust block. Any small amount of longitudinal thrust which may remain unbalanced is received by an adjustable grooved thrust bearing at the end of the spindle, beyond the main bearing. This, which is contained in the oil box *c* (Fig. 7), is shown to a larger scale in section in Fig. 8. The thrust bearing (Fig. 8) consists of seven collars on the spindle revolving in a grooved bush, which is split longitudinally

into halves with separate longitudinal adjustment to allow any wear to be taken up, so that end shake is prevented and the endwise position of the shaft is maintained with great precision. This device also gives a means of regulating the amount of clearance over the tips of the turbine blades. The thrust bearing, like the main bearing, runs in a bath of oil.

The main bearings are of a special construction which is admirably adapted to insure easy running at a high speed and to damp out vibration. The shaft (Fig. 8) rotates in a phosphor-bronze sleeve, outside of which are slipped three concentric steel tubes, fitting loosely over one another. The outermost tube (Fig. 8) is a loose fit in the casting which forms the seat of the bearing. Oil is continuously and freely fed to the bearing from a cistern above, under a head of some 6 inches, and drains into a chamber below, from which it is automatically pumped back to the cistern. The oil is used over and over again. In this way the small clearance between each tube or sleeve and the one outside of it is kept charged with a film of oil, with the effect that while the shaft retains a necessary small amount of freedom to adjust itself by lateral displacement, the viscosity of the films acts as a powerful damper to prevent oscillation from being set up. The working of the bearing is perfectly satisfactory, and the damping action is so great that the shaft may even be put considerably out of balance without causing the vibration to become excessive or making the bearings run hot. In the ordinary conditions of balance the shaft carrying the turbines, the main armature, and the exciter armature runs at 80 revolutions per second, with a steadiness and quietness which are most remarkable.

The shaft passes out of the turbine case at each end through a lantern brass or steam gland. The whole shaft is in three lengths; the first part carries the turbines, the second carries the armature of the main dynamo *g* (Fig. 5), and the third part that of the exciter dynamo *h*. The parts are coupled by means of a square-bored sleeve slipped over squared ends. The couplings are placed in the middle of long double bearings at *j* and *k*. These, as well as the end bearing at *l*, are all formed by concentric tubes, and work drowned in a sea of oil, as already described

for the end bearing. The oil chambers are connected by pipes, so that a single oil pump maintains the circulation in all. The pump, which is shown at *m* in Fig. 5, is driven by an eccentric which receives its motion from a worm, *n*, on the main shaft, working in oil, between the main bearing and thrust bearing of Fig. 8.

The governing of the machine tested was accomplished by a novel and extremely effective appliance. Steam was admitted to the turbine in a series of gusts by the periodic opening and closing of the double-beat lift valve shown in Fig. 7. This valve was operated by means of a steam relay in mechanical connection with the turbine shaft, so that the valve was opened regularly once in every twenty-eight revolutions of the shaft. The duration of each gust was controlled by an electric solenoid, which was connected as a shunt to the field magnets, but was compounded so as to keep the volts constant. The core of the solenoid was hung from the end of a long lever, *o*, Fig. 5. The fulcrum *p* of this lever was periodically moved up and down by means of a link connecting it with the eccentric which also served to drive the oil pump. The short end of the lever *q* controlled the valve of the steam relay. Each periodic movement caused a gust of steam to be admitted to the turbine, the duration of the gust depending on the height of the distant end of the lever. The effect was, that at full load the gusts became blended into an almost continuous blast, the lift valve closing only momentarily, or not at all, in each of the periodic movements; under any lighter load each interval of admission alternated with an interval during which the steam was completely shut off. The action of the governor was most satisfactory. The periods of admission were so frequent that they caused no material throbbing of speed nor any variation of volts sensible on a voltmeter. There was no hunting, and the freedom from friction was greater than I have seen in any governor. I repeatedly threw the whole load, amounting to over 130 electrical horse power, on and off suddenly, without causing more than a momentary variation in the volts. The governor was sensitive, quick and certain in its action to quite an exceptional degree.

Fig. 5.

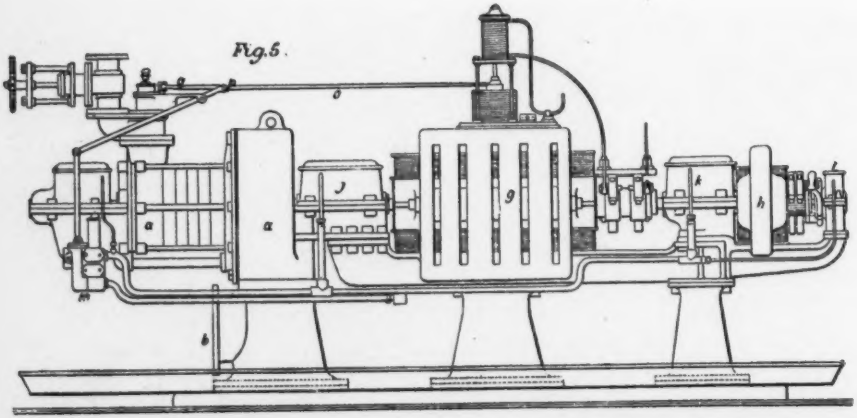


Fig. 6.

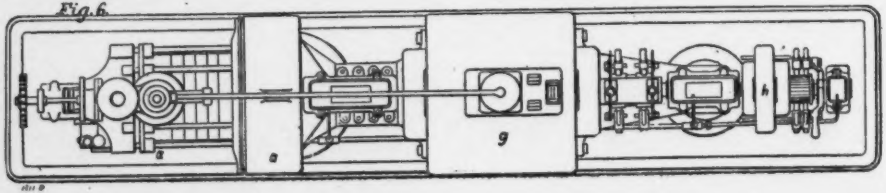


Fig. 9

Fig. 10.

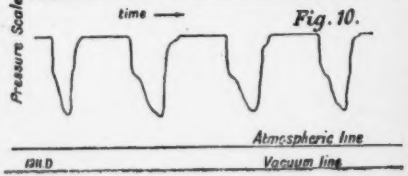


Fig. 7.

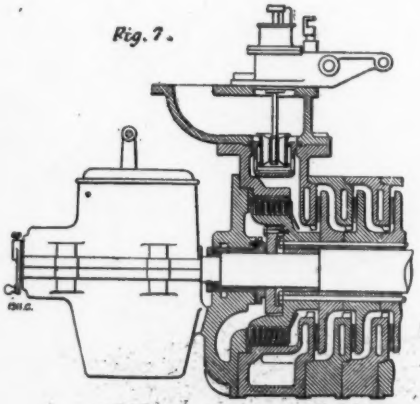
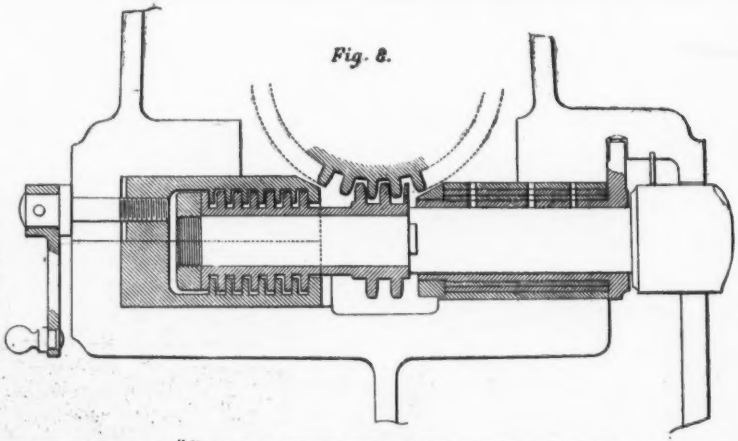
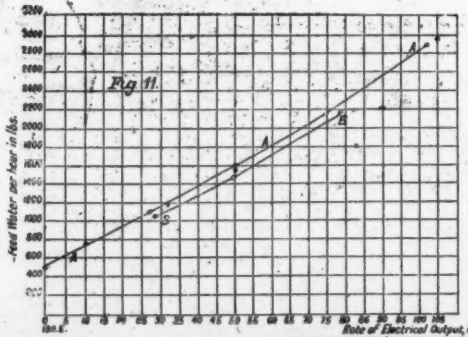
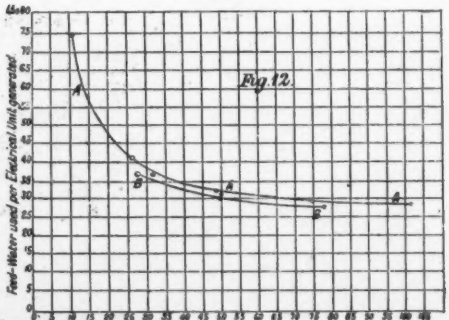


Fig. 8.







TRIALS OF PARSON'S STEAM TURBINE AND DYNAMO, AUGUST, 1892

AA.—Steam superheated to about 400° Fah.; Continuous current trials ○; Alternating current trials ●

BB.—Steam superheated to 465° Fah.; Continuous current trials

By applying an indicator at the admission end of the turbine chamber, below the double-beat valve, observation was made of the pressure during the periodic admission of steam; this was done by pulling the paper drum of the indicator as steadily round as possible by hand while the pencil rose and fell. Figs. 9 and 10 are examples of diagrams obtained in this way. In Fig. 9 the load was about one-half the maximum; in Fig. 10 it was about three-quarters. The pressure which these diagrams show during admission is about 4 pounds less than that shown at the same time by a pressure gauge on the steam pipe above the governor valve.

The machine tested was primarily constructed to generate alternate currents up to 50 ampères, with a potential of 2,000 volts, and in some of the trials the original alternate-current armature was used. But thinking it desirable to make the tests of efficiency depend on measurements of continuous rather than of alternating currents, in order to avoid any uncertainty which may be held to attach to estimates of the work spent in an alternate current circuit, I suggested to Mr. Parsons the desirability of winding a continuous-current armature specially for these trials. He adopted the suggestion, and most of the trials have accordingly been made with a continuous-current armature, wound to give 400 ampères at 250 volts. The original exciter was still used to supply current to the field magnets.

It may be said at once that the results of the continuous-current trials, where the electrical measurement of the work done is of a perfectly simple and straightforward character, are in close agreement with those of the alternate-current trials.

The main armature was about 2 feet 6 inches long over the body by 9 inches in diameter. The weight of copper on it was only 33 pounds, or $\frac{1}{3}$ pound per kilowatt of output.

Steam for the turbine was supplied at a pressure of 100 pounds per square inch by gauge from a locomotive boiler which was capable of giving enough for the full load of 100 units per hour. The feed water was measured by putting it through a tank, the graduations and total capacity of which I checked by weighing water into it. The contents of this tank were delivered into a

second tank, from which the feed pump drew its supply, and in which the level of the water was adjusted to have the same value at the beginning and end of each period of observation. The level of water in the boiler was kept as nearly as possible constant throughout.

In all the statements which follow of the results of these trials the quantity of feed water named is the gross quantity supplied to the boiler, no deduction having been made for leakage, blow off at the safety valve, or other loss.

On its way to the turbine the steam passed through an improvised superheater consisting of eight 9-foot lengths of cast-iron pipe 8 inches in internal diameter. This superheater was placed in the main boiler flue, and, except in a special series of trials noted below, was heated merely by the hot gases from the boiler tubes. The draft was forced by a steam jet from an auxiliary boiler. Notwithstanding the small size of the improvised superheater, this sufficed to bring the steam from 338 degrees Fahrenheit, the temperature of saturation, to about 400 degrees Fahrenheit. In a special series of trials extra superheating was produced by lighting a furnace built for that purpose in the brickwork inclosing the superheater. With the help of this furnace, the temperature of the steam in these special trials was raised to about 465 degrees Fahrenheit.

Three separate sets of trials were made, August 11 to 15, 1892. In the first set the steam was superheated by means of the hot gases from the boiler furnace only. The temperature approached, but did not exceed, 400 degrees Fahrenheit, which, as the boiler pressure was 100 pounds per square inch above the atmosphere, corresponds to about 60 degrees of superheating. In this set of trials the continuous-current armature was used, and the amount of feed water was determined for six different grades of output, from no electrical load up to a load in which the output was at the uniform rate of 102 Board of Trade electrical units per hour, the current being spent on a bank of coils. The results of this set of trials are set forth in Table I. The output stated is the amount of electrical work done upon the external circuit, and does not include the output of the exciter. The volts were

measured by three Cardew voltmeters, which were tested against each other, and one of them against a Thomson balance. The ampères were measured in the following way: A low resistance frame consisting of many bare thick wires of platinoid, grouped in parallel, was arranged as a shunt to a mirror galvanometer, which was provided with a strong controlling magnet, so that the whole current of about 400 ampères could pass without causing an inconveniently great deflection, and without heating the wires of the shunt materially. In series with this was placed (1) an Evershed ampèremeter which had been carefully calibrated by reference to a Thomson balance, and (2) two Siemens' electro-dynamometers, one of which could take the strongest current while the other was suitable for comparatively weak currents only. The constant of the shunted mirror galvanometer was determined in the low-power trials by comparing its deflection with the readings of the Evershed and of the more sensitive of the two Siemens' instruments. These were then cut out to allow stronger currents to pass, and in the trials under heavy load a further check on the constant of the mirror galvanometer was furnished by the readings of the larger electro-dynamometer. The mirror galvanometer, the constant of which remained unaltered throughout, served to connect the readings of all the currents, from the lightest to the heaviest loads. The agreement between the various measurements was perfectly satisfactory.

In the second set of trials the object was to test the effect of additional superheating. A special furnace, built into the uptake of the boiler flue, was made to give additional heat to the superheater, forcing the temperature of the steam to 465 degrees Fahrenheit. In this set of trials the continuous-current armature was again used, and the measurements were made in the same way as in the first set. Three different grades of output were tested. The results are given in Table II.

In the third set of trials the alternate-current armature was used, giving 2,000 volts at a speed of 4,800 revolutions per minute, which made the frequency of alternations 80 periods per second. Here the current was directly measured by the Evershed and Siemens' instruments, and the volts were determined

by (1) a Cardew voltmeter furnished with a resistance specially wound to enable it to read 2,000 volts, and independently (2) by another Cardew voltmeter with a step-down transformer having a ratio of one to twenty. The output was taken to be the product of the effective volts and the effective ampères. In these alternate-current trials the electrical energy was absorbed by a water resistance formed by sticking two rods, to serve as terminals, some 10 yards apart in a pond, the amount of resistance between them being adjusted by pulling the rods out or in to expose more or less of their surface to contact with the water. In this third set of trials the steam was moderately superheated, as in the first set, by the hot gases of the boiler flue only—its temperature again approaching 400 degrees Fahrenheit. The results are given in Table III. The close agreement of them with the corresponding continuous-current trials (Table I) is important, as supplying evidence that in alternate-current trials conducted in this manner the effects of lag in the external circuit are immaterial; in other words, that the electrical work is properly measured by multiplying the effective volts by the effective ampères. The difference between the alternating and continuous-current measurements is less than 1 per cent. of the output at full load.

In each of the trials the turbine was kept running for a sufficient time beforehand to establish a nearly uniform régime, and the trial was kept up long enough to prevent any material error from coming in through inexact readings of the water level in the boiler-gauge glasses. In each trial the amount of the feed water was determined during two successive equal periods of time, to test the agreement of these with each other. The air pump and feed pump were driven by donkey engines, the steam for which was supplied from a separate boiler, and is not included in the figures given below. What the tables give is the gross amount of feed water actually delivered to the main boiler, from which the whole supply of steam for the turbine was drawn.

The temperature of the steam was read by a thermometer placed in a mercury pocket in the steam pipe close to the turbine. A pressure gauge placed there showed that the pressure

was, at full load, between 2 pounds and 3 pounds per square inch less than the pressure at the boiler. The amount of superheating in the trials of Table I was comparatively small under light loads, because the boiler fire was not then being forced; from half load to full load it was nearly uniform.

The results are also exhibited in the curves, Figs. 11 and 12. The rate of electrical output is shown in relation to the whole consumption of feed water per hour in Fig. 11, and in relation to

Table I.

TRIALS WITH CONTINUOUS-CURRENT ARMATURE, WITH STEAM SUPERHEATED BY THE GASES FROM THE BOILER FIRE ONLY.

Pressure by gauge on boiler.	Temperature of steam.	Load in electrical units per hour.	Feed water per hour, in pounds.	
Lb. per sq. in.	*Deg. Fahr.*		*Total.*	*Per unit.*
96	335	0.1	480	.....
102	365	10.2	760	74.5
100	356	27.0	1.110	41.1
102	400	49.2	1.590	32.3
100	390	74.5	2,170	29.1
103	398	102.0	2,900	28.4

Vacuum in full-power trial: By mercury column at exhaust, 27½ inches; by gauge on condenser, 28½ inches; barometer, 29.9 inches; temperature of injection water, 73 degrees Fahrenheit; speed, 4,500 revolutions per minute.

Table II.

TRIALS WITH CONTINUOUS-CURRENT ARMATURE, WITH EXTRA SUPERHEATING.

Pressure by gauge on boiler.	Temperature of steam.	Load in electrical units per hour.	Feed water per hour, in pounds.	
Lb. per sq. in.	*Deg. Fahr.*		*Total.*	*Per unit.*
102	463	28.3	1,060	37.5
102	468	49.5	1.480	29.9
101	465	78.4	2,170	27.7

Vacuum by gauge on condenser, 28½ inches; barometer, 29.5; temperature of injection water, 72 degrees Fahrenheit.

Table III.

TRIALS WITH ALTERNATE-CURRENT ARMATURE AND WATER RESISTANCE: SUPERHEATING BY THE GASES FROM THE BOILER FIRE ONLY.

Pressure by gauge on boiler.	Temperature of steam.	Load in electrical units per hour.	Feed water per hour, in pounds.	
Lb. per sq. in.	*Deg. Fahr.*		*Total.*	*Per unit.*
99	367	31.6	1,180	37 3
97	394	49 9	1,550	31.1
103	399	105.2	2,970	28.2

Vacuum in full-power trial: By mercury column at exhaust, 27¼ inches; by gauge on condenser, 28½; barometer, 29.6; temperature of injection water, 72 degrees Fahrenheit.

Table IV.

CONSUMPTION OF FEED WATER AT VARIOUS RATES OF OUTPUT, WITH SUPERHEATING.

Rate of output in electrical units, per hour.	Feed water per electrical unit.	
	With superheating to about 400° Fahr.	With extra superheating to 465° Fahr.
20	48	
30	39	36½
40	34½	32
50	32	29½
60	30½	28½
70	29½	28
80	29	27½
90	28½	(27)
100	28½	(27)

the consumption of feed water per electrical unit in Fig. 12. The line *AA* in each diagram refers to the first set of the present trials—those of Table I—which were made with continuous currents and moderate superheating. The points of observation are marked thus O. The points marked ●, which lie very close to this curve and a trifle below it, are for the tests made with alternating currents (Table III).

The line *BB* in each diagram relates to the trials with extra superheating (Table II). The points of observation are marked thus O.

To facilitate comparison, the amount of feed water used per electrical unit at various rates of output, as measured from the curves of Fig. 12, is given numerically in Table IV.

The trials show that a very considerable advantage is realized by moderate superheating. To superheat the steam from, say, 338 degrees Fahrenheit, the temperature of the saturation for a boiler pressure of 100 pounds to 400 degrees Fahrenheit requires the addition of barely 30 units of heat, which is less than 3 per cent. of the heat taken up in the boiler. With steam superheated to this extent the consumption of full load is less by one-fourth than the consumption in the old trials. How much of this increase in economy is due to superheating alone cannot well be distinguished without further trials, as the comparison is complicated by the other improvements referred to at the beginning of this report. It is clear, however, that superheating is responsible for a great part of the difference. Apart from the increased volume of the working substance the advantage of superheating is to be ascribed in part to the prevention or reduction of the condensation at entry, which would otherwise take place in consequence of the intermittent character of the admission, and in part to its influence in keeping the steam dry during its expansion, and thereby reducing the internal resistances. At full load, when the steam enters in a nearly continuous blast, the latter effect is no doubt the more important.

The further advantage realized by superheating to 465 degrees Fahrenheit is comparatively small, especially at high loads. From evidence given by the temperature of the turbine case, it was clear that this amount of superheating not only kept the steam dry throughout its whole course through the turbine, but left it still considerably superheated at the end. The part of the case next the exhaust, which had been quite cool in the trials of Table I, was decidedly hot in those of Table II. This observation agrees with the result of calculation, which shows that an initial temperature of about 443 degrees Fahrenheit would be high enough to prevent the steam from becoming wet as it expands. It may be concluded from this consideration, as well as from the results of the trials, that very little increase of effi-

ciency is to be brought about by carrying the superheating further than this.* It seems, therefore, undesirable to push the superheating to a higher point than can readily be reached by the use of a superheater in the boiler flue. With a superheater of moderate size the hot gases of the uptake will furnish as much superheating as need be aimed at, and as much as is sufficient to secure highly economical working.

The general result of the trials is to demonstrate that the condensing steam turbine is an exceptionally economical heat engine. The application to it of moderately superheated steam has put the performance of the turbine on a level with that of the best steam engines of the ordinary type. A consumption of 27 pounds or 28 pounds of steam per electrical unit, at full load, and 30 pounds or 32 pounds at half load, is a result that does not need to have its significance emphasized. The efficiency under comparatively small fractions of the full load is probably greater than in any steam engine, and is a feature of special interest in relation to the use of the turbine in electric lighting from central stations.

The consumption of 28 pounds per unit corresponds to 20.9 pounds per electrical horse power hour. To facilitate comparison with other engine trials, it may be useful to estimate from these results what may, by analogy, be called the "indicated" horse power of the turbine, that is to say, the mechanical work done by the steam on the turbine blades. The curves of Fig. 11 are nearly straight lines, and by prolonging them backwards to meet the base line produced, it appears that the idle work, that is to say, the work done without useful output, was equivalent

* Taking the initial pressure as 115 pounds per square inch absolute, the temperature of saturation is 338 degrees Fahrenheit. Superheating to 443 degrees Fahrenheit makes the total energy of each pound of steam at admission 1,235 thermal units. Each pound does work equal (at full load) to about $\frac{1}{28}$-th of an electrical unit; and the thermal equivalent of this is 122 thermal units. Hence, if we neglect the small loss of heat which occurs through radiation and air convection from the turbine case, steam at 100 pounds pressure initially superheated to 443 degrees Fahrenheit will retain at exhaust a total heat of 1,113 thermal units. This makes it just saturated, for 1,113 thermal units is the total heat of 1 pound of saturated steam at the final pressure of 1 pound per square inch.

to 27 kilowatts, or 36 horse power. The effective work at full load, the equivalent of 100 electrical units per hour, was 134 electrical horse power. Hence, if the idle work had the same value at full load as when the machine was running light, the total work done by the steam at full load would be 170 horse power, and the effective work (134 horse power) would be 79 per cent. of the total. But the idle work certainly increased when the machine was loaded, and it will be nearer the truth to assume that the effective work was not more than 75 per cent. of the total work. This would make the total work about 179 horse power. On this basis, a consumption of steam at the rate of 28 pounds per electrical unit is equivalent to 15.7 pounds of feed water per "indicated" horse power hour, and 27 pounds per unit is equivalent to 15.1 pounds per "indicated" horse power hour. Similarly, the consumption of half load is equivalent to about 17 pounds per indicated horse power hour.

No allowance, as has been said, was made in these trials for leakage of steam and water from the boiler. It is well known that some leakage occurs under the most favorable conditions, and that if the quantity of steam used were measured after passing through the engine—as is often done in tests where a surface condenser is used—the results would be more favorable than those obtained by direct measurement of the feed. In the present instance it appeared (from separate observations) that the losses by leakage amounted to about 90 pounds per hour, or, say, 3 per cent. of the whole consumption in the full-power trials. If this allowance were made, the quantities of steam per horse power hour and per unit would be reduced below the values stated above by about 3 per cent. in the full-power trials, and by about 6 per cent. in the half-power trials.

By applying the indicator at various parts of the turbine case, the range through which the pressure varies as each gust of steam passes, and the fall of pressure from one set of turbine rings to the next throughout the series, may be examined. This was done during the trials, with the result of showing that the apertures of the several turbines were not adjusted in the best possible relation to one another; in particular it was found

that the turbine rings on the large disc at the condensing end gave too free a passage, and were doing less than their proper share of work. The readjustment of areas indicated by this test as desirable will, no doubt, secure even better results.

Apart from the other possible applications of a peculiarly light and efficient high-speed motor, the turbine dynamo in its present state is, in my opinion, eminently well fitted for central station use, not only on account of its economy of steam under both heavy and light loads, but also on account of its exceptional lightness and compactness, its small first cost, its independence of foundations, its freedom from vibration, its steady governing, its simplicity, the ease with which it is handled, and the moderate outlay which it may be expected to require under the heads of maintenance, oil and attendance. So far as I have been able to judge, the performance of the machine is as excellent as its details are ingenious.

On page 572 of our fifty-fourth volume (November 4, 1892), we published a report of a test of one of the Hon. C. A. Parsons' condensing steam turbines, driven by superheated steam. This test was made by Professor Ewing, and showed remarkable economy. Quite recently another test has been made by Professor A. B. W. Kennedy, and has given the wonderful result of 20.3 pounds of water per electrical horse power hour. By this the steam turbine is placed among the best of the engines used in the direct driving of dynamos. The following is the text of the report:

"REPORT ON TRIALS OF PARSONS' STEAM TURBINE DYNAMO AND ALTERNATOR.

"19 Little Queen street, Westminster, S. W.
"May 30, 1893.

"In accordance with the request of Messrs. C. A. Parsons & Co., I went to Newcastle on the 12th of April last, and spent the two following days in making a series of trials with one of Mr.

Parsons' turbo-motors, driving a continuous-current dynamo, having an output of 150 units.

"The machine tested was in external dimensions almost exactly the same as that tested in August last by Professor Ewing, but by a rearrangement of the plates and discs its output has been very considerably increased. Its nominal maximum capacity is 150 units when working with 120 pounds of steam pressure; but it gave this output without apparent difficulty at 100 pounds steam pressure, as will be seen below.

"As the motor has been so recently described in Professor Ewing's report and elsewhere, it is unnecessary that I should say anything as to its mechanical construction. The particular machine tested had six high-pressure single discs, and one low-pressure double disc, the two sides of the latter being in parallel. It ran at about 4,500 revolutions per minute.

"The tests made were essentially directed to the determination of the quantity of steam used per electrical horse power hour by the motor at different loads. The water measurement was carried out by means of a little tank holding 370 pounds of water (as checked by direct weighing). From this tank water was allowed to run into a somewhat larger one below it, from which the feed pump drew its supply. The feed pump itself was worked by steam from a second boiler, which also supplied steam for the air-pump engine. The boiler used for supplying steam to the motor was a small boiler of the locomotive type, capable of running only at 100 pounds pressure. The boiler was so small for this work that there was no difficulty in keeping the feed practically continuous throughout the trials, and in keeping the water level very steady. When running at full power the feed-measuring tank lasted only eight minutes, so that it was easy to get a large number of points upon the water line in the diagram.

"The steam from the boiler passed through a series of superheating tubes on its way to the engine, these tubes being surrounded by the waste gases passing from the boiler to the chimney. In all the trials made, except where the engine was running light, it will be seen that there was a very considerable

amount of superheating attained in this manner. It is to be regretted that it had not been found possible beforehand to make the boiler and its connections perfectly steam-tight. There were a not inconsiderable number of small leaks taking place, the total amount of which may quite well have considerably impaired the apparent economy of the motor. It was impossible for me to take these leaks, such as they were, in any way into account, and the water consumption which I give below, therefore, includes the whole of them, whatever they may have been. I need hardly point out that all these errors, without exception, were against the motor, and not in favor of it.

EXPERIMENTS ON PARSON'S STEAM TURBINE DYNAMO AND ALTERNATOR.

HEATON WORKS, APRIL, 1893.

	A.	B.	C.	D.	E.	F.	G.
Duration of trial in minutes	35.5	34.0	72.0	93.0	122.0	46.5	7.0
Mean boiler pressure...lbs. per sq. in.	95.8	98.5	97.0	94.6	94.5	97.1	97.0
Corresponding mean temp.....deg. F.	335.2	337.	336.	334.4	334.3	336.1	336.
Actual mean steam temp. close to engine.....deg. F.	330.3	331.3	356.	371.	401.	391.	380.
Amount of superheating	...	...	20.0	36.6	66.7	54.9	44.
Mean vacuum.....lbs. per sq. in.	14.3	14.1	14.28	14.28	13.95	14.11	13.8
Mean injection temp.....deg. F.	59.	63.3	64 4	58 6	70.7	61.7	...
Mean hot-well temp.....deg. F.	62.6	68.9	72.9	75.2	89.8	80 6	...
Mean revolutions per minute.	4,268.	4,385.	4,480.	4,475.	4,655.	4,625.	4,592.
Mean current.....amperes.	...	...	105 5	260.3	420.7	482.5	576.5
Mean electromotive force.....volts.	265.1	267 2	264.9	264.3	263.3	254.9	264 7
Mean kilowatts	...	...	27.94	68.8	110 8	123.0	152.6
Mean electrical horse power	...	...	37.45	92.21	148 5	164.9	204.6
Total water used.....lbs.	370.	370.	1,480.	3,330.	6,290.	2,590.	...
Total water per hour.....lbs.	625.	653.	1,233	2,148.	3,094.	3,342.	...
Water per kilowatt hour.....lbs.	...	...	44.1	31.2	27.9	27.2	...
Water per electrical H.P. hour....lbs.	...	...	32.0	23.3	20.8	20.3	...

"The dynamo which was used in the experiments had a continuous-current armature, not intended to take more than about 120 units. This was the largest power for which the boiler could supply steam for more than a very short time, and this fact limited the maximum power at which any water measurements could be made. The whole of the electrical measurements were made by zero methods, using a Crompton potentio-meter and standard Clark cells. A standard platinoid resistance of .001 ohm, which was sensibly free from temperature error for very much larger currents than those which I used, was employed in connection with the current measurements. The work done by

the motor was taken up upon an artificial resistance of spiral wire divided into sections to suit the different powers required.

"During each trial the steam pressure and water level were noted each time the measuring tank was emptied. The temperature of the steam, the vacuum, and the speed of the engine were noted at the same time or more often. The electrical measurements were made at regular intervals of five or ten minutes, according to the duration of the trial.

"On the diagrams,* page 125, are shown graphically the results of six trials of the motor and dynamo, two running light (excited only), one at about 28 kilowatts, one at about 70 kilowatts, one at about 110 kilowatts, and one at about 123 kilowatts. These are lettered respectively in the diagram with the letters from A to F.

"Experiment E, at about 110 kilowatts, is the one which I looked upon as the most important, as it was run at the largest power for which the steam could be kept up for any length of time. The actual duration of the run was just over two hours, in which time 17 tanks of water were used. It will be seen from the diagram how very uniform both the power and the water were during the whole of the run, and having obtained so many points on what appeared to be a straight line, it did not appear worth while to prolong the trial further. In this trial the mean output was at the rate of 110.8 kilowatts, or 148.5 electrical horse-power.

"The boiler pressure was 94.5 pounds above the atmosphere, and the average amount of superheating was 66.7 degrees Fahrenheit. The average vacuum shown by the gauge was 13.95 pounds per square inch, the pressure of the atmosphere being equivalent to 30.3 inches of mercury, or, say, to 14.86 pounds per square inch. The total water used per hour was 3,094 pounds, which is equivalent to 27.9 pounds per kilowatt hour, or 20.8 pounds per electrical horse-power hour.

"It is unnecessary that I should go over in detail the figures obtained upon the other tests; they are given at full length in the annexed table. An examination of the observed points,

*These diagrams are not reproduced.—EDITOR.

shown on the diagram, shows that for all four experiments—C, D, E and F—the water consumption was exceedingly regular throughout the whole duration of the test. I regret that it was not possible to carry on the highest power test (F) for more than three-quarters of an hour, but at this power the boiler was very uncomfortably forced, and the armature also was being somewhat hardly treated. It will be noted, however—and this forms far the best test of the accuracy of the water measurements—that the four points in the diagram which represent the total water used per hour follow very exactly Willans' law; that is, they lie upon one straight line.

"In the two trials, A and B (which were made on two different days), when the motor was running empty, circumstances rendered it only possible to use one tank full of water each time. There are, therefore, in these cases no such checks afforded as in the other tests by the straightness of the water line throughout the whole duration of the trial. The two tests, however, agree with each other very well, and the two corresponding points, as will be seen, lie very nearly in their proper place at the commencement of the line which represents the total water used per hour (Fig. 3).

"The amount of superheating appeared to depend, to a considerable extent, as was natural, upon the work which was being done by the boiler—that is to say, upon the amount and temperature of the chimney gases. Running empty, there was no superheating, or rather, the superheating had fallen to nothing by the time the steam reached the engine, close to which its temperature was measured. I have no doubt that there may have been, even then, a very considerable amount of superheating given to the steam after it had left the boiler. In trial C, which was really made immediately after trial D, the superheating commenced at the point at which it had reached during D, but it will be seen that after half an hour it fell to a much lower point, and remained there steadily. In trials D and E the amount of superheating rose from the beginning until it attained what appeared to be a more or less normal amount for the corresponding power. In trial F the temperature was still rising

when other causes (which I have already mentioned) compelled me to stop the experiment. After all the other trials were ended I had the motor run up to give an output of 150 kilowatts, in order simply to see whether it could actually deal with this load. It was impossible to keep up steam for more than a few minutes under these conditions, and, therefore, no water measurement could be made, but I found that with a steam pressure falling from 100 pounds down to 90 pounds the motor could drive the armature with an output of 152.6 kilowatts, apparently without the slightest trouble. The vacuum at this time was 13.8 pounds per square inch, and the steam temperature had only had time to reach 380 degrees Fahrenheit when the machine was shut down. The motor was running about 4,600 revolutions per minute, as will be seen from the table.

"The table above gives the principal figures, totals and means, etc., connected with the seven trial runs.

"It is obviously not necessary for me to point out that the figures given in this table are figures of unusual excellence in economy, for they certainly rank among the best results hitherto obtained in the direct driving of dynamos by condensing machinery. The construction of the motors allows the advantage of superheating to be carried to the fullest extent, without any chance of injury to any parts of the machine, and no doubt this wise use of superheating has contributed, to no small extent, to the exceptionally good results which have been obtained.

"Since making the trials of which I have now summarized the results, I have been able to have special experiments made, with a view to determining to what extent the superheating has contributed to the result obtained. It is not necessary that I should give details as to these experiments, but their leading results may be summed up by saying that at about 35 electrical horse-power the steam used without superheating was the same as with superheating, but that the difference gradually increased until at 100 electrical horse-power it was about 8 per cent. The working of the boiler did not allow the non-superheating experiments to be carried farther than this, but if the same law of increase of economy held good up to the full power of the

machine, its actual water consumption, as tested, must have been about 10 per cent. less than it would have been without superheating—a very notable difference. Of course this figure must be taken as only approximate, but it shows that even without superheating, the motor would show very good results.

"I have only further to say that the engine worked throughout the trials without giving the slightest trouble in any way, either at low or at high loads. The throttle valve was full open in each case, and the engine ran upon its governor, which appeared to control it in a satisfactory manner.

"ALEX. B. W. KENNEDY."

XU

THE YALE & TOWNE MFG. CO. CRANE BUILDERS

MODERN CRANES.

By B. H. Warren, Ass't Eng'r, U. S. Navy (Retired), Manager Crane Dep't, the Yale & Towne M'f'g Co.

ELECTRIC TRAVELING CRANES.

Overhead traveling cranes were but little known, and were practically not in use in this country, until the Yale & Towne M'f'g Co., in 1876, began a campaign in their favor, which brought them prominently to public attention, and which led ultimately to their general adoption. Such cranes had been used in Europe, especially in England, during the previous fifteen or twenty years, but had never found favor here. Since 1876, however, they have steadily advanced in popular appreciation, and are now generally recognized as the best, most efficient and most economical type of crane for use wherever the conditions make them available.

The earliest overhead traveling cranes, except those operated by hand, are believed to have been operated by direct steam, generated in a boiler carried on the bridge. For indoor use it became necessary to operate them by power derived from some fixed source and transmitted thence to the crane. This was done at first by the square-transmitting shaft, and by the slow-moving rope of hemp or wire. Later it was accomplished by the so-called "flying rope," introduced by Ramsbottom, of Crewe, and also by applications of hydraulic mechanism. A few years since the development of the electric motor made it possible to use this, the latest and best mode of transmission of power, as the means of transferring the motive force from a fixed source to the moving bridge of the crane. Nearly every crane builder has been through these experiences of change and development, and all have, for the present at least, adopted electric transmission as the best method yet discovered.

From the foregoing it will be understood that the term "electric crane" refers primarily to the mode of transmitting power to the crane. It follows that the power having been transmitted electrically is in form available at the crane for use in one or more electric motors. Hence it becomes best to adopt such motors for each function, in preference to converting the electric current at once into dynamic force and distributing it on the crane by shafts, gears and clutches, as was formerly done.

The illustrations selected to accompany this description of electric traveling cranes, as built by the Yale & Towne M'f'g Co., show the construction of a crane built for, and supplied to, the Administration of the World's Columbian Exposition at Chicago, and installed in the central bay of Machinery Hall. The crane in question has a capacity of twenty tons, distributed between two trolleys, each of ten tons capacity, and has a span of seventy-five feet. Its length of longitudinal travel in Machinery Hall was thirteen hundred and fifty feet, making the total floor area which it served 101,250 square feet, or approximately two and one-half acres. It was used before the opening of the Exposition for the installation of the greater part of the heavy exhibits in Machinery Hall, including not only those in the central bay, but most of those in the north and south bays. During the Exposition it was fitted with a deck and convenient seats, and was utilized in carrying passengers, for a fee, up and down the building, affording an exceptionally fine view of the building and its contents, and contributing to the revenues of the Administration. It is being used since the close of the Fair in removing the heavy exhibits, and will ultimately be disposed of. It has frequently been traveled at a speed of from 500 to 600 feet per minute, but in ordinary service lower speeds have been used.

The first essential in a traveling crane is a bridge, spanning the space between the longitudinal tracks. Except for very small cranes, this bridge always consists of two parallel girders, carrying usually on their upper chords the tracks on which the trolley is to move. In the earlier days of crane building, the longitudinal travel rarely exceeded 50 or 60 feet per minute, and in Europe this practice still usually obtains. America, however,

although long behind Europe in appreciation and introduction of the traveling crane, has developed it very rapidly, and already demands from it greater efficiency and far higher speeds than have been attempted heretofore or elsewhere. While the speed of bridge travel remained low, the principal stresses to which the bridge was subjected were in the vertical plane, and were due to the weight of the bridge itself, and to the vertical reaction of the suspended load. With the advent of the present higher speeds, which approximate about ten times those established by European practice, the bridge became subjected to stresses in the horizontal plane, due to the inertia of the bridge itself, and of its suspended parts, which are found frequently to approximate those in the vertical plane. Hence, has arisen the necessity of modified methods of girder construction, designed to give horizontal, as well as vertical, stiffness. The method adopted by the Yale & Towne Manufacturing Co., for accomplishing this certainly gives great stiffness with a very light and open structure, and is believed to be the best which has yet been proposed.

Referring now to the drawings, Plate I shows the construction of the bridge, Fig. 1 being a plan or top view, Fig. 2, a side elevation, Fig. 3, an end elevation, and Fig. 4, an end elevation to a larger scale. The details of the bridge are also well shown in Plate II, Fig. 2. Each main member of the bridge consists of a plate girder, having a cross-sectional area and depth proportionate to the vertical stresses it is to resist, and to its length of span. The resistance to horizontal stress is obtained by reinforcing the top and bottom chords of the main girder by connecting to each a light lattice girder in the horizontal plane, giving this horizontal girder a depth of several feet, and proportioning it to the span and capacity of the crane. As these light horizontal girders cannot support themselves, and would tend to sag at their outer edges or chords, a third light lattice truss or girder is provided and placed, in the vertical plane, parallel to the main girder, but in line with the outer chords of the two horizontal girders. The final effect of this is a very rigid girder, each member of which has great depth, one member (the plate girder receiving the vertical reaction of the trolley and load) hav-

ing a large moment of inertia, while each of the other three is of lattice construction, usually very open and light. Both the main girders and the vertical auxiliary girders are supported at each end by the end trucks, into which they are framed, and to which they are well secured. In spans of more than moderate lengths diagonal bracing is used to connect the upper and lower chords of the main girder with the outer chords of the auxiliary girders. The horizontal space occupied by this construction is found to be always within that which is desirable as wheel base for the end trucks, so that it in no wise encroaches on the effective travel of the bridge.

From this construction of the bridge many advantages arise. In the first place, it avoids all twisting strains on the main girders which otherwise would arise from attaching to one side of these the transverse shaft and other heavy mechanism. It provides for the convenient and effective support of the transverse shaft and other bridge mechanism in the interior spaces inclosed by the light girders, and also affords ample support for the footway on each side of the bridge, without resort to brackets projecting from, and therefore tending to twist, the main girders. The construction admits of obtaining any degree of horizontal stiffness deemed desirable, with a minimum addition to the dead weight of the crane. All strains, whether static or dynamic, are symmetrical and susceptible of accurate determination. This type of girder may be built with either a curved or straight bottom chord. Usage heretofore has made a curved bottom chord, pleasing to the eye, but with the high speeds of bridge travel now demanded it becomes better engineering to use a straight bottom chord. This is due to the fact that, where a curved bottom chord is used, it follows necessarily that the central portion of it drops below the point of attachment of the ends. The inertia to this underhanging, or pendulous, portion tends to retard it when the bridge is suddenly put into rapid motion, and to thus set up a vibration, or twisting movement, of the girder, which is often very noticeable in curved girders of the ordinary box form. By making the bottom chord straight, all of these objections disappear, and the horizontal stiffness of the bottom chord be-

comes practically equal to that of the top chord. With the high speeds now used, this is a matter of such serious importance as to outweigh æsthetic preferences and to justify the adoption of the straight bottom chord in all cranes of large capacity or long span.

The electric current is carried to the crane by means of two copper conductors, located either below or above the bridge, and supported either from the posts carrying the longitudinal track, as in the present case, or from the wall or frame of the building rising above the crane, or from the roof which covers it. In either case the current is taken from these wires by rolling trolleys of the usual type, and is then distributed to the motors on the bridge by means of controlling switches conveniently located on the operating cage or platform. These switches may be of any approved form, and are usually mounted each on a separate standard, or all on a shelf or stand. The main thing is to have them all within convenient reach of the operator when standing in a position where he faces the center of the floor covered by the crane. The location of the platform itself may be at any point on the bridge which is preferred, at either end or in the middle, above, below, and on either side, the flexibility of electric connections giving peculiar facility in this matter. As a rule, the platform is usually placed at one end of the bridge and projecting somewhat below it, thus giving the operator a clear view in all directions.

The mechanism for propelling the bridge consists of an electric motor, which is preferably placed at or near the center of the bridge, as shown in Figs. 1 and 2, Plate I, although in small cranes it is often placed at one end. This motor is geared, by a simple train of spur gears, to a traverse shaft, extending across the bridge, each end of this shaft being geared likewise to one or more of the truck wheels at each end of the bridge. The rotation of the shaft thus propels the bridge longitudinally by rotating a driving truck wheel at each end. The alignment of the bridge is preserved partly by use of double flanged truck wheels and a broad wheel base for each truck, and partly by means of the transverse shaft, which is purposely made of large diameter in

order to insure substantial identity of motion at each end. Ample experience has demonstrated the entire reliability of this method for cranes of all capacities and spans, and at all customary speeds. In the crane under consideration the conditions were somewhat unusual, the span being 75 feet, the length of longitudinal travel 1,350 feet, and the speed 600 feet per minute, although the crane was usually traveled at about one-half this speed by preference. The acceleration of the bridge when starting from a state of rest is accomplished, as slowly as may be desired, by the switches and rheostats controlling the bridge motor. Its retardation when stopping is controlled by shutting off all current from the motor and also by means of a brake applied to either or both truck wheels in the usual manner. It will be noted from the drawings that the peculiar form of bridge girder adopted serves admirably to support the tranverse shaft and its mechanism without introducing any twisting or other unsymmetrical strains in the girder.

The construction of the trolley is clearly shown by the drawings in Plate II. The trolley itself is framed entirely of wrought material, chiefly channel bars, the use of cast iron being confined entirely to gearing and boxes, with the single exception of the chain drum, which, however, has a steel shaft through its entire length. This construction possesses much greater flexibility, and also much greater strength and safety, than is feasible with cast iron. The hoisting chain is wound in two parts, but in a single wrap, on a double grooved drum. The two parts of chain pass from the drum over two sheaves in the running block, and thence up again over an equalizing sheave fixed in the trolley frame. Although the load is thus carried on four parts of chain, the purchase is only a double one, as two of these parts are wound simultaneously on the barrel. This implies a little more and much heavier gearing than where a three-fold or four-fold chain purchase is used; the objection to the use of increased purchase by means of a larger number of parts of chain, is the greatly increased amount of wear which comes upon the chain by reason of the extra sheaves with the friction and the greater number of times the links are obliged to turn upon each other.

Referring to Fig. 1, Plate II, it will be seen that the electric motor for hoisting is located in the center of the trolley near its front. The armature shaft carries a large and small pinion, each gearing into a spur wheel on the second shaft of the hoisting train. A clutch located between these wheels engages either of them with its shaft, and is conveniently operated by a pair of solenoids controlled from the operating platform. This second shaft carries, at the left, a pinion driving a spur wheel on the third shaft, the pinion on which latter engages with a heavy gear which is keyed to the chain barrel. The hoisting motor is used both in hoisting and lowering, the load never being permitted to run down under gravity alone (except in the case of small cranes) and to ensure perfect safety, two brakes are provided—an electric and a mechanical brake. The electric brake is located at the right-hand end of the second shaft, and consists of a powerful strap brake operating on a suitable brake wheel. A weight hangs on the brake lever tending constantly by gravity to apply the brake and thereby prevent motion of the shaft. A solenoid magnet is fixed over the brake lever in such a way that whenever the electric current is passed through this solenoid the lever is raised and the brake released. The instant the current ceases to flow the lever drops by gravity and the brake is again applied. The magnet of this solenoid is in circuit with the hoisting motor, so that whenever current is applied to operate the latter the magnet lifts and releases the electric brake, but whenever the current is cut off, to stop the motion of the motor, the brake is instantly and permanently applied by gravity. The brake thus assists in checking the motion of the parts whenever the current is cut off, and also serves to hold the whole train of gears at rest, except when current is supplied to the motor. It follows, therefore, that the load cannot be lowered except by the application of an electric current to the motor in a manner which reverses the motion of the motor. This is done by the operator whenever he desires to effect lowering. If, however, no further device were provided, gravity would operate, especially in the case of heavy loads, to accelerate the speed during lowering and

to increase it to a dangerous degree. This is prevented by the use of the mechanical brake.

The automatic mechanical brake is located at the left-hand end of the second shaft, as shown in Fig. 1, Plate II. To facilitate its description, however, reference is made to Plates III, IV and V, showing the details of its construction. It consists essentially of a Weston disc friction brake, applied to a heavy ratchet wheel on the end of the shaft in such manner as to permit the ratchet wheel to rotate with the shaft in hoisting, and to prevent the rotation of the wheel backwards except when the second shaft is rotated backwards by power supplied from the motor, in which case the friction discs contained within the ratchet wheel are caused to slip smoothly on one another, thus permitting the load to descend quietly, without acceleration, so long as the reverse motion of the motor is continued. Whenever this ceases the automatic brake instantly and permanently prevents further descent of the load. Briefly, this is effected by connecting the part which carries one of the series of the friction discs with the driving pinion on the second shaft, as shown in Fig. 1, Plate IV, and connecting the part which carries the other series of discs with the shaft itself. The pinion, therefore, can only be driven by the shaft when the two sets of discs are pressed together into frictional engagement. This is accomplished by means of the well-known Weston system, the details of which are clearly shown by Plate IV.

The use of the heavy ratchets required would ordinarily cause a constant and loud noise during hoisting. To obviate this, and also to insure prompt and certain action of the two differential pawls, a novel device has been employed, the details of which are shown by Plates III and V. It consists primarily of a pair of spur wheels, one carried on the extreme end of the second shaft, the other driving a short parallel shaft which serves as the pin or fulcrum for the two pawls. It follows that whenever the second shaft revolves in either direction the pawl shaft revolves in a contrary direction. Each pawl has a counter-weight, which tends by gravity to keep the pawl in engagement with the ratchet wheel. In addition, a spring plunger within each pawl increases

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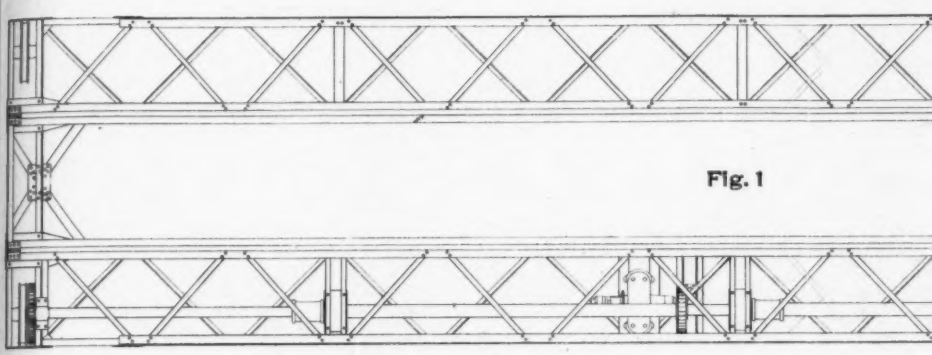


Fig. 1

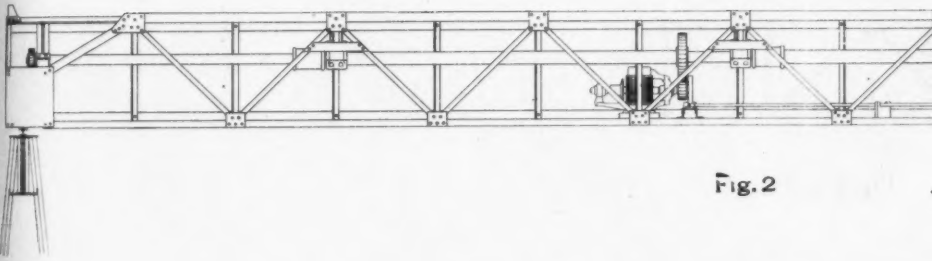


Fig. 2

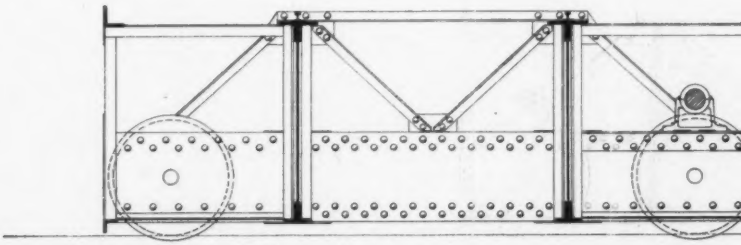
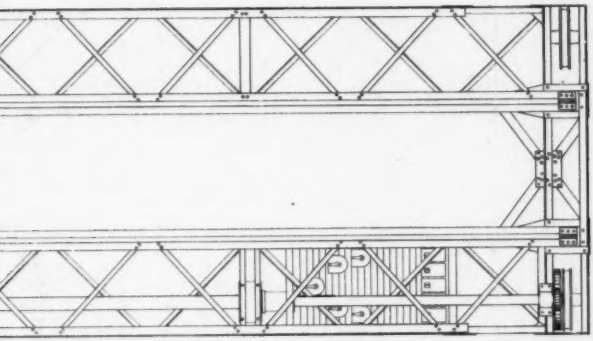


Fig. 4

Plate 1.



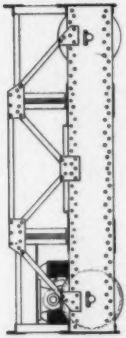
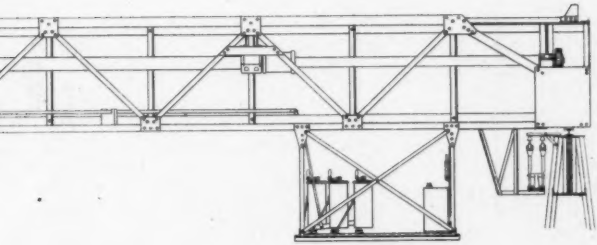


Fig.3

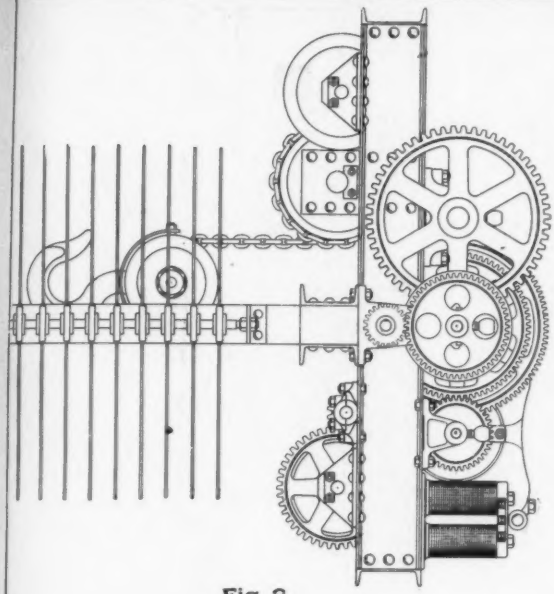


20 TON ELEC. TRAV. CRANE

BRIDGE

THE YALE & TOWNE MFG. CO., STAMFORD CONN. U.S.A.

10380



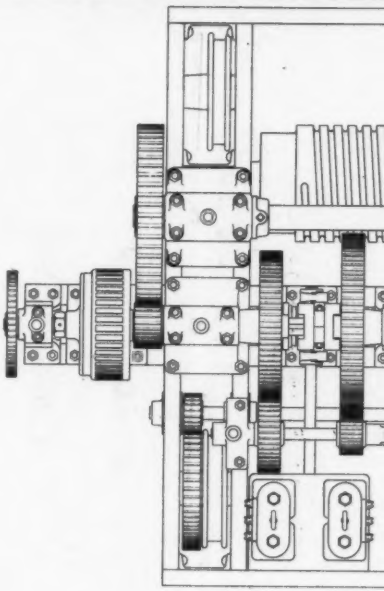


Fig. 2

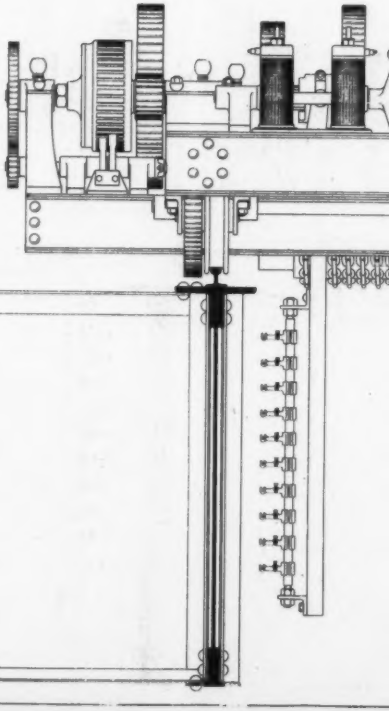
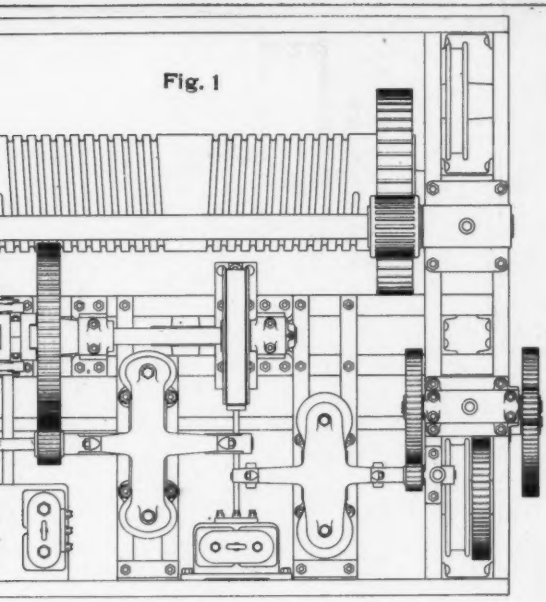


Plate II

Fig. 1



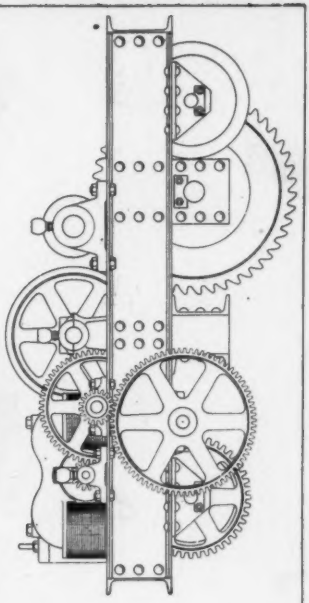


Fig. 4

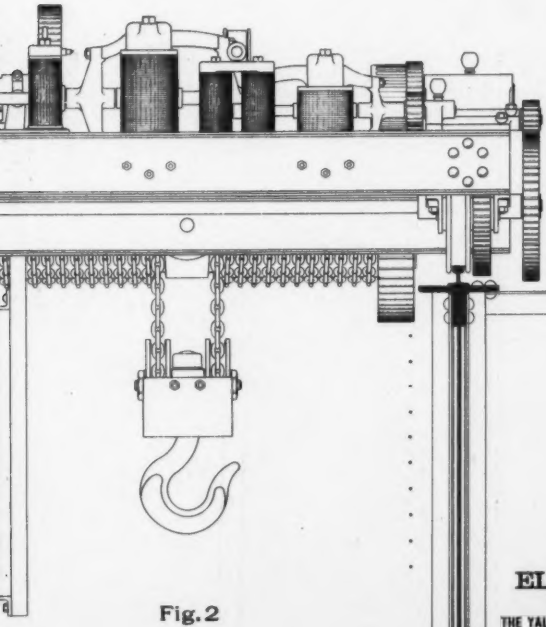


Fig. 2

20 TON
ELEC. TRAV. CRANE
TROLLEY
THE YALE & TOWNE MFG. CO. STAMFORD CONN. U.S.A.
10379

Plate III.

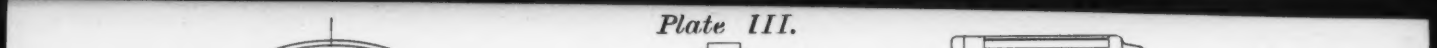
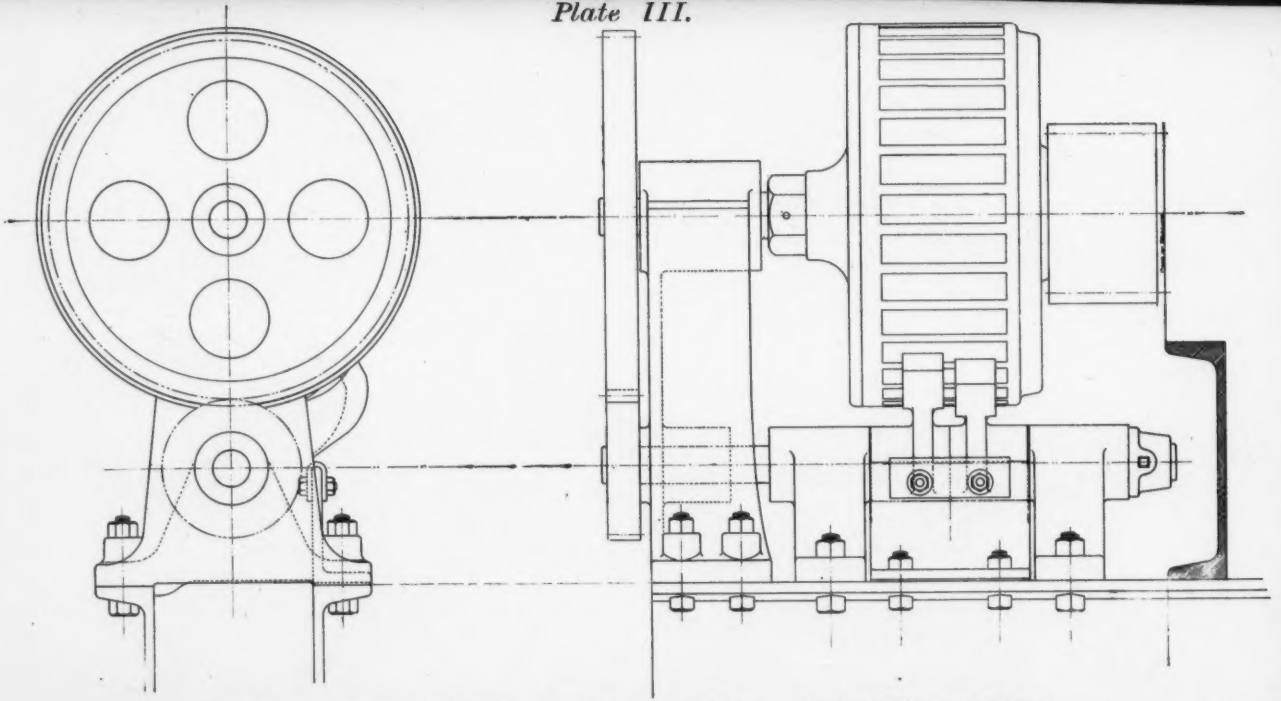


Plate III.



THREE-MOTOR ELECTRIC TRAVELING CRANE. MECHANICAL BRAKE.

THE YALE & TOWNE CO., STAMFORD, CONN.

Plate IV.

Plate IV.

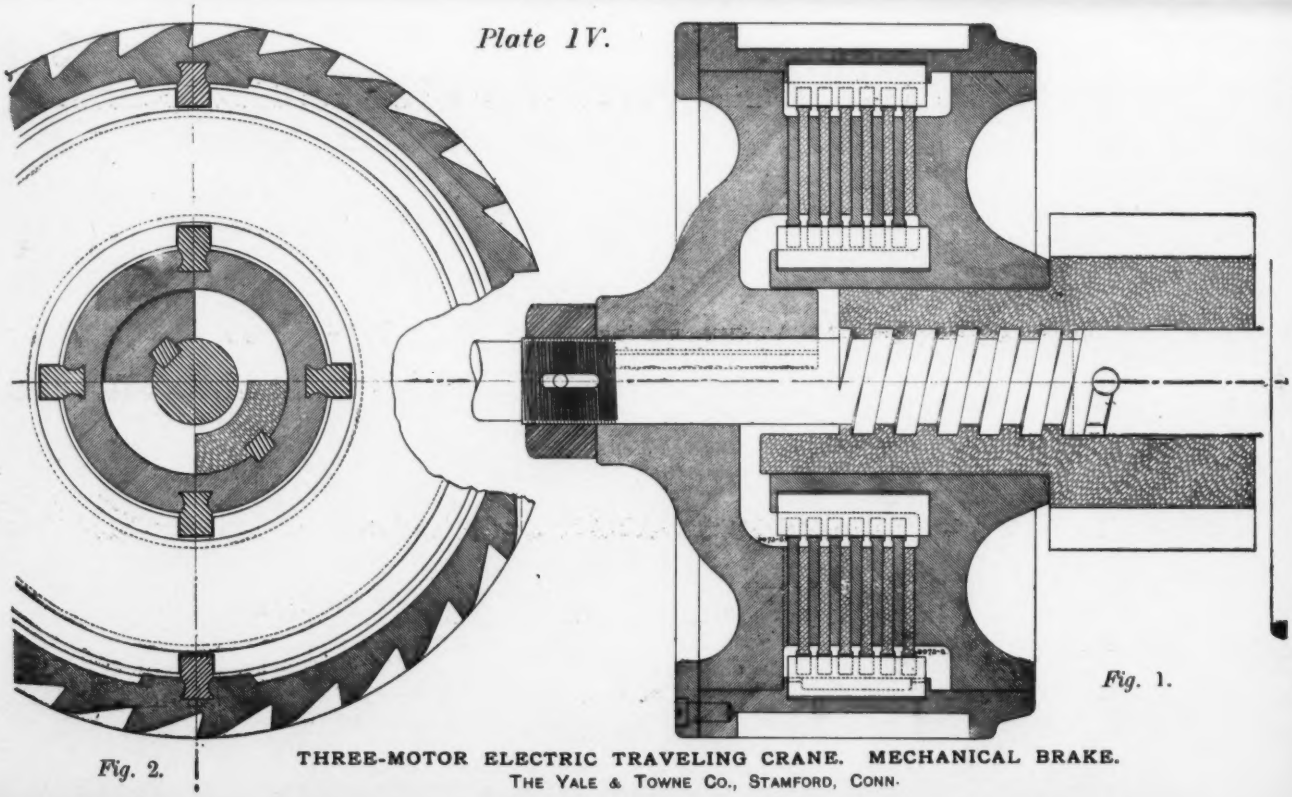
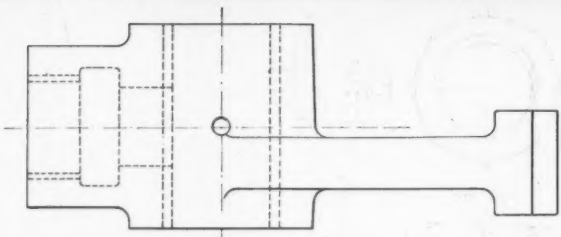


Fig. 2.

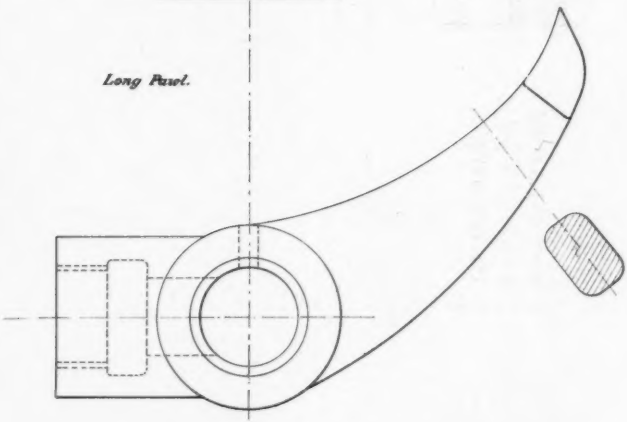
Fig. 1.

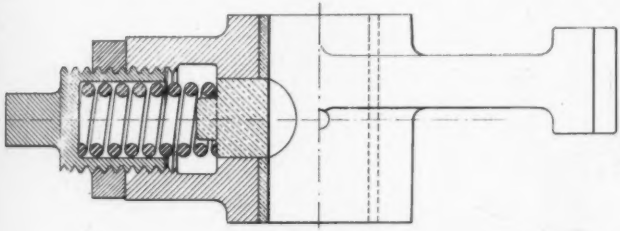
THREE-MOTOR ELECTRIC TRAVELING CRANE. MECHANICAL BRAKE.

THE YALE & TOWNE CO., STAMFORD, CONN.

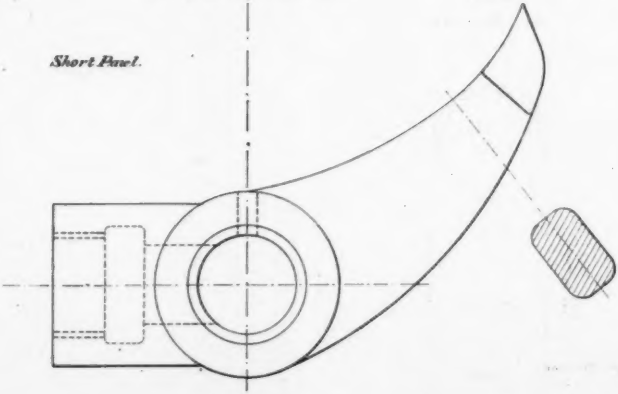


Long Pawl.





Short Pawl.



Lock

Pawl S

Pawl Pi

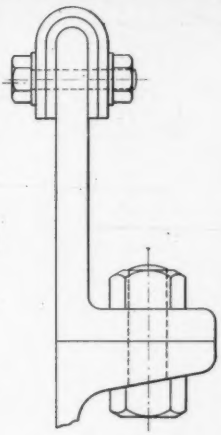
Pawl Bushing

ck Nut.

el Springs.

Plug Screw.

Pawl Fr. Block.



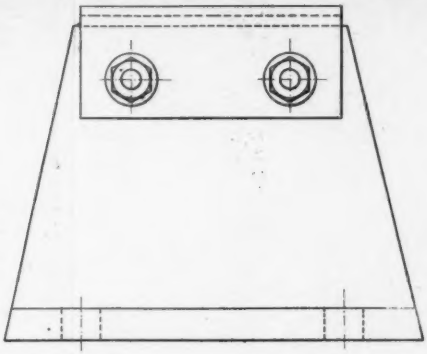


Plate V.

3 Motor Electric Trav. Crane.

Trolley "F"

Pawls.

the frictional contact between the pawl and its shaft, the amount of this friction being adjusted by a regulating screw behind the springs. The relative positions of the parts are such that the friction thus developed tends to throw the pawls into engagement with the ratchet wheel during the act of lowering, and tends to turn the pawls out of engagement during the act of hoisting. The motion of the pawl shaft being quite rapid, the friction developed between it and the pawls is sufficient to cause the latter to tend to instantly rotate in whichever direction the shaft rotates whenever the latter is in motion. The arc of vibration of the two pawls is limited in each direction and is very small, being merely sufficient to permit them to entirely disengage themselves from the ratchet wheel. Whenever, therefore, hoisting occurs the two ratchets are instantly vibrated, by friction, out of engagement with the ratchet wheel, and are thus held so long as the latter moves in the direction of hoisting, the pawls thus being silent. If hoisting ceases, the pawls tend by gravity to fall into the ratchet wheel. If motion is reversed in the direction of lowering, friction co-operates with gravity to throw the pawls instantly into engagement. This simple arrangement gives great promptness and certainty to the action of pawls, and at the same time makes them absolutely silent in action.

It remains to consider the mechanism for propelling the trolley on the bridge. This is shown by the figures on Plate II. The trolley motor is shown in Fig. 1, at right-hand lower corner. The pinion on its armature shaft drives a gear wheel on the second shaft, a pinion on the other end of this drives a gear wheel on the third shaft, and a pinion on each end of the latter engages with a spur wheel attached to a trolley truck wheel on each side of the trolley. The latter, like the bridge, is thus propelled by the traction of one of the two truck wheels resting on each longitudinal rail. The truck wheels are double flanged, and a broad wheel base assures proper guidance of the trolley.

The chief characteristics of this crane may now be summed up as follows:

A construction of bridge giving maximum stiffness with minimum weight, and such that all stresses are symmetrically re-

sisted; a construction of trolley giving maximum strength with minimum weight, and combining flexibility, simplicity and complete accessibility; a method of bridge propulsion which ensures efficiency, smoothness of motion, simplicity and economy of construction, and which dispenses with all necessity for longitudinal racks with their accompanying noise, wear and friction; a method of trolley propulsion equally simple, smooth and effective; an arrangement of hoisting mechanism which causes the hook to move always in a vertical line, without either rotation or translation, consisting of a simple train of spur gearing, which provides for two changes of speed or power, and is controlled by an automatic electric brake in circuit with the hoisting motor and which is further guarded by an automatic mechanical brake which holds the load positively and safely at all times except when the motor is reversed, and then permits the load to descend smoothly and safely at a speed determined by the speed of the motor; finally, but by no means least, are the important qualities of great simplicity of construction, both in the frame-work and mechanism, of complete accessibility to every part for lubrication, cleaning, inspection and repair, and of facility of manipulation and control by the operator, whose working platform may be located at any point which the requirements of the case make preferable or most convenient. These results have become possible by the recent rapid development of electrical science, and are attained by the skillful combination of mechanical and electrical appliances, each selected and designed with reference not only to its own functions but to its relations with the others with which it is intended to co-operate.

ON THE PRESENT POSITION OF WATER-TUBE BOILERS AS APPLIED FOR MARINE PURPOSES.

By J. T. Milton, Esq., Chief Engineer Surveyor to Lloyd's Registry of Shipping.

[Read at the Thirty-fourth Session of the Institution of Naval Architects, July 13th, 1893.]

At the present time the boiler question is attracting considerable attention amongst marine engineers, who have by no means arrived at a unanimous conclusion as to the types of boilers which best satisfy the peculiar requirements of different classes of vessels. To see that this is so, we have only to look at the plans adopted in different vessels having presumably the same requirements to find great divergency of practices. For instance, in the war vessels of our own and foreign countries we see large vessels, which may have to keep the sea for long periods, in some cases fitted with ordinary tubular boilers worked with the closed stokehold system of forced draft, and in others with water-tube boilers worked with natural draft; while in another case, a reference to our own Transactions will show that a combination of ordinary cylindrical and locomotive-type boilers has been adopted. In smaller types of ships, which may not be required to be continuously under steam, we find vessels having apparently similar requirements fitted in some cases with ordinary cylindrical boilers; in others, with the locomotive-marine type, while in some water-tube boilers of peculiarly light construction are used.

Turning to merchant vessels, we find some passenger steamers of great speed fitted with ordinary boilers working under natural draft, others employing different forms of forced draft with the same type of boilers, while in still other cases water-tube boilers are used. Again, while most cargo vessels are fitted with boilers

working under natural draft, several are fitted with forms of forced or induced draft, some using only plain boiler tubes, while, on the other hand, "Serve" tubes are not uncommon.

In view of this divergency of practice, it is thought that it would be interesting to draw attention to, and to put on record, what is being done at the present time with water-tube boilers, especially in view of the fact that, owing probably to prejudice arising from the failures several years ago of a few unsuccessful types of these boilers, their use in British vessels has till very recently been confined to a few torpedo boats, or to vessels of similar class. It is proposed, therefore, in this paper to give a statement of some cases in which water-tube boilers have been successfully used, and in which they may be fairly said to have passed out of the experimental stage, and also to give a short description of the various types of boilers employed.

It is well to bear in mind that the objects aimed at in designing boilers for different classes of vessels may be entirely different, and to remember that the success or otherwise of any design should be judged from the way in which it fulfills these special objects, and not from a point of view of general utility for all purposes. As an extreme instance, it is evident that a boiler which would give satisfactory results in a cargo vessel would not be of much service in a torpedo boat.

The use of water-tube boilers, instead of those of the ordinary types, has generally arisen from the desire of obtaining some or other of the following advantages. The relative importance of these not always being the same has no doubt led to the various designs being adopted in different cases.

(1) The means of obtaining higher working pressures than are practical with ordinary boilers, owing to the excessive thickness of plates which would be necessary both for the shell and also for the heating surfaces.

(2) Economy of maintenance, due to the comparative ease with which in some designs every part of the boiler, both external and internal, can be examined and cleaned, and if necessary renewed, it being with some types possible to entirely reboiler a vessel without opening decks, &c.

(3) A decrease of space required, and also of weight of boilers and accessories necessary for producing a given power, or an increase of power obtainable with a given weight and in a given space.

(4) It is also generally claimed for all classes of water-tube boilers that they are less liable than ordinary boilers to derangement or damage through accident or neglect, and also that, even in the case of rupture, the damage which would result would be made less than with ordinary boilers, owing to the much less quantity of water they contain.

There is one important point, viz: "durability," which is indirectly included in the Condition 2, as to which experience is at present deficient. Although in special cases ordinary boilers have been replaced within two or three years, it is well known that few have become worn out in less than ten or twelve years, when treated with ordinary care, while many cases are within our knowledge of such boilers being now in use after twenty years' service. It is obvious that no such record of service can yet be recorded with water-tube boilers in general, although lengthened experience has been obtained with some special kinds.

Turning to actual cases of the use of these boilers, we must frankly admit at the outset that we are indebted for our experience to the French engineers, who successfully used these boilers before they were placed in any British vessel. In the French Navy they are not looked upon as experimental, for, according to the "Carnet de l'Officier de Marine," edited by Mons. Léon Renard, it appears that the whole of the French war vessels which are now being built, or which have been lately finished, are, or will be, furnished with water-tube boilers. Those in the larger vessels are either of the Belleville or the Lagrafel-D'Allest types, these being employed in about equal proportions, while in smaller and lighter vessels boilers of the Oriolle, Du Temple, Normand, Thornycroft, and similar types are used.

It appears that so long ago as 1879, the despatch vessel *Le Voltigeur* was fitted with Belleville boilers. She has since seen considerable sea service and her boilers have given satisfaction. After two commissions of about three years each, her boilers

were reported to have needed no repairs. We find also that the *Milan* launched in 1885 and the *Alger* in 1889, have also been fitted with these boilers. In view of the present practice of the French naval authorities it can only be concluded that their use has given satisfaction.

Turning to merchant vessels, so long ago as 1871 the S.S. *Isere*, of 287 tons, was fitted with Lagrafel boilers; in 1873 the S.S. *Blidah*, of 267 tons, and *Medeah*, of 236 tons, were similarly fitted, and their boilers are still in these vessels. In 1874 the the S.S. *Paoli* and *Spahis* were fitted with this type of boiler, which were in use for seven and eleven years respectively, until the vessels were lost. The S.S. *Colon*, *Cabile*, and *Caid* were also fitted with these boilers in 1874, 1875, and 1876, and although these vessels are now withdrawn from service, their boilers were in use for many years. The S.S. *Liban* of 1,332 tons, built in 1882, was refitted with the Lagrafel-D'Allest boilers in 1891, and the S.S. *Dom Pedro*, of 2,999 tons, was similarly refitted at about the same time. The former of these vessels is engaged in general trade, the latter is running regularly between Europe and South America.

In 1884 the then new steamer *Ortégal*, of 3,570 tons, belonging to the Messageries Maritimes Cie., was fitted with compound engines with cylinders of 36 inch and 64 inch diameter by 42 inch stroke, and with Belleville boilers. The S.S. *Sindh* belonging to the same Company was also reboilered with this type several years ago. The Company's latest and largest vessels the *Australien*, built in 1889, the *Polynésian*, in 1890, and the *Armand Behic* and *Ville de la Ciotat*, built in 1892, are each fitted with similar boilers. These last four vessels are each of about 6,500 tons, they are fitted with triple-expansion engines indicating regularly about 5,000 I.H.P. at sea, which gives them a mean speed on the round voyage of about 15½ knots.

The Oriolle boiler made by Mons. P. Oriolle, of Nantes, was fitted last year in the S.S. *Mitidjah*, a vessel of 1,160 tons, and has also been fitted in several smaller vessels. Experience with this boiler is not so great as with the types previously mentioned.

The Babcock & Wilcox boiler has been fitted in some small

vessels, and recently a large boiler working at 200 pounds pressure has been fitted in the British S.S. *Nero*, a vessel of 1,053 tons, owned by Messrs. T. Wilson & Sons, of Hull. Experience with this boiler will be watched for with great interest.

Turning our attention again to war vessels, we find that in our own navy the Thornycroft and Yarrow boilers have given great satisfaction in torpedo vessels, in their comparative lightness in proportion to their evaporative power, and have enabled higher speeds to be obtained than could be realized with the older form of locomotive-marine boilers. The former type, also, is being fitted to H.M.S. *Speedy*, a torpedo cruiser of 4,500 I.H.P. It has been successfully fitted in some foreign war-vessels of similar class, and both these types of boiler are to be used in the specially fast cruisers, whose speed of 27 knots recently stated by the First Lord of the Admiralty, could not possibly be realized except by the use of both engines and boilers which will give the maximum of power on the minimum of weight.

In the French Navy the Normand and Du Temple boilers are used for similar vessels.

For particulars of the actual results realized by some of these boilers, reference may be made to "Engineering," of January 16, 1891, and December 23, 1892, and to "The Engineer," of July 15, 1892.

The first type of boiler to which attention will be drawn is that of the Babcock & Wilcox Company, shown in Fig. 1, which represents that fitted in the S.S. *Nero*. The working pressure in this case is 200 pounds per square inch, but it is evident that, so far as considerations of strength only are concerned, there need be no difficulty in constructing similar boilers to work at very much higher pressures. In this boiler there are two sets of tubulous heating surfaces, each possessing separate circulating systems. One of these is a modification of the well-known land boiler made by this firm, and consists of a number of pairs of "headers" of sinuous form, connected by bundles of tubes, having an inclination of about 1 in 4, placed immediately over the fire. The modification from the land boiler being that each tube of the latter is replaced by a set of four smaller tubes, the

ends of each set of four being expanded through one tube-door. Above these sets of tubes, and partly outside of the casing, is a pair of receivers—the upper being a steam chest, and the lower being, in ordinary working, about half full of water and half of steam. The circulation in this part of the boiler takes place from the lower receiver, down the back headers, upwards through the sloping tubes and the front headers, then through the connecting pipes into the receiver. The bottom of each of the back headers is connected to a settling chamber, to which the blow-off cock is attached.

The other circulating system consists mainly of a number of vertical tubes on both sides of the boiler, forming part of its casing. The tubes are connected at the bottom to two horizontal pipes of square section, and at their top ends they either enter directly into the lower receiver below the water line, or are connected to two other horizontal pipes, which open into the receiver at about the water level.

The circulation takes place from the receiver, down the three or four back tubes, along the bottom horizontal pipes, up the other vertical tubes into the receiver either direct or through the upper horizontal pipes. In the front of the boiler there are other tubes forming part of the framework of the boiler, which also are connected to this circulating system.

Above the boiler, in the base of the chimney, is placed a tubulous feed heater consisting of five horizontal headers on one side, and four on the other, connected across from side to side by means of numerous pipes so arranged that the water, being delivered from the feed pump into the bottom box on one side, passes through these pipes from side to side, and finally emerges from the upper box, being thence led to the boiler. The circulation in this heater is thus purely a mechanical or forced circulation depending on the working of the feed pump. The heating surface of the heater is only about one-sixth of that of the boiler; and, as it is placed in the coolest part of the boiler, it is not expected that sufficient heat will be extracted by it to raise the water to the temperature of ebullition, so that no steam will be formed in it, but the whole of the evaporation will be

effected in the boiler itself. In this particular boiler the tubes over the fire are 1½ inches internal diameter, and 7 feet long; the vertical tubes at the sides are 3 inches diameter, spaced 5 inches from center to center, and about 9 feet long; while the feed-heater tubes are 3 inches diameter, and about 7 feet 6 inches long.

The side casing consists of 2 inches of brickwork resting against the vertical tubes, then a sheet of ¼-inch asbestos, backed by wrought-iron plates. The front and back of the boiler consist mainly of doors made to give access to the headers and to the numerous small tube doors. There are three firing doors, and the grate area may be made either continuous from side to side, or it may be divided by brick partitions into three grates, one for each door, according to the plan which may be found to give better control over the firing, etc.

A peculiarity in this boiler is that all the joints of the tubes with the headers, cross tubes and receiver, are made with ordinary rolled or expanded joints, no screwed stay tubes being used. The makers contend that these joints, when properly made, give perfect tightness and sufficient structural strength to resist all strains likely to come upon them; while, by avoiding varying thickness of tubes in the same part of the boiler, they prevent any straining taking place due to expansion with varying temperatures. Even the square tubes are connected by having round holes made at the adjoining parts, and round nipples expanded into both holes. In the event of accident or mismanagement of the boiler occurring, such as shortness of water, overheating through deposits, etc., the makers consider that the loosening of a few only of the tubes would result, and that the holding power of the remainder would be much more than sufficient to prevent any general dislocation of the boiler.

To give access to the tube ends for the purpose of expanding them there must necessarily be numerous holes which have to be closed by special doors. In this boiler these doors are placed outside, not inside, as is usual in ordinary boilers, so that the pressure tends to force them off. They are made with faced joints, metal to metal, no jointing of any kind being used. The

nut of the holding bolt is also faced on to the door, and is close ended. The plug or dog placed inside the boiler is made in one piece with the bolt, and is so formed that, in the event of the breakage of a bolt and its door falling off, a slight leakage only will result, and not a rush of steam, water, etc.

The importance of such a detail as this will be appreciated when it is considered that there are several hundreds of such doors in an ordinary sized boiler.

The Lagrafel-D'Allest boiler, which is shown in Fig. 2, is made by the Forges et Chantiers de la Méditerranée, at Marseilles, and by the Fraissinet Company of the same city. It possesses a certain resemblance to the internal part of the Babcock & Wilcox boiler. The numerous sinuous headers of the latter are, however, replaced by water chambers, those of the front and back each forming only one water space. These chambers or water spaces are formed of plates, retained in parallel positions, about 5 inches apart, by means of numerous screw stays. They are closed at the bottom and sides, but they open at their upper portions into a cylindrical steam chest, which is nearly horizontal, sloping a little towards the back of the boiler. The chambers extend down to about the level of the fire grate. They are connected by a number of water tubes placed above the fire, these tubes forming the main portion of the heating surface. A few tubes are also fitted at the sides of the fire, in order to protect the sides of the casing.

In the manufacture of the boiler both plates of the chambers have to be pierced with as many holes as there are tubes, those in the outer plates being slightly larger in diameter than the tubes. The tubes are secured to the inner plates by means of expanded joints, access for this purpose being obtained through the holes in the outer plate, in the same manner as in the Babcock & Wilcox boiler; the latter holes are closed by specially constructed doors, which, in this case, are placed *inside* the boiler, each being secured by a bolt and cross bar, the joint being made by means of a thin asbestos washer and a ring of thin copper wire.

It should be noted that there are no stay tubes in this boiler. The water chambers are each connected to the horizontal steam chest at their upper portions, and at this part, therefore, do not need such stays. At the lower parts the necessary strength to resist separating the slabs is obtained by the friction of the tube joints, which are all expanded or rolled joints. The tubes generally employed are about $2\frac{3}{4}$ inches outside diameter, $\frac{1}{4}$ inch thick, and are pitched about 4 inches apart from center to center. "Serve" tubes are recommended by the makers for the lower row of tubes.

The working water level is a little above the bottom of the receiver, and the circulation of the water and steam is such that the water supply enters each tube at its lower end from the back water space, passes along the tube, where part of it is vaporized, the mixture of steam and water escaping into the other water chamber and rising direct into the receiver without having to pass through the upper tubes, as in the Belleville boiler. The water so carried over traverses the bottom of the steam receiver and passes down the other water chamber, where the process is repeated.

The feature distinguishing this boiler from all others is the arrangement made for the circulation of the products of combustion amongst the tubes. The boilers are usually arranged in pairs, each part having its own feeding and water circulation, independent of the other; but a combustion chamber is common to the fires of both parts, being arranged between the two nests of tubes.

The tubes are placed mainly over the fire, the bottom row being at a height of about two feet above the grate bars. Over the bottom row of tubes and resting on them, preventing the passage of the gases between the tubes, are placed a number of specially-shaped tiles, and a similar set is fitted upon the top row. Baffle plates are fitted to cover the spaces between the tubes for about the upper two-thirds of their depth at the sides remote from the combustion chamber. These arrangements are shown in Fig. 2, the arrows showing the direction which the products of combustion are compelled to take. They pass

under the lower row of tubes into the combustion chamber, thence they proceed sideways between the tubes, emerging at the lower edge of the side of the nest of tubes, whence they proceed under the steam chests on their way to the chimney.

In the Lagrafel, which was the older form of this boiler, the products of combustion passed directly from the fire up amongst the tubes, as is now done in some other forms of water-tube boiler. The reason for altering the design was owing to its being considered that the gases immediately arising from the fire have not been properly burned, and that by passing them directly amongst the tubes they become cooled below the critical temperature at which union between the gases and the oxygen of the air takes place; so that imperfect combustion and loss of economy results. If this is so in practice, most of the other types of water-tube boiler must be inefficient from this cause.

The interior of the tubes and water chambers can be readily examined or cleaned through the numerous small doors, and the removal of any tube in case of necessity can be made in a short time, the tube being either replaced or the holes plugged.

The Oriolle boiler, shown in Fig. 3, made by Mons. P. Oriolle, of Nantes, bears some resemblance to the Lagrafel boiler, being constructed of two water chambers connected by a number of tubes. Only one of these chambers, however, is connected with the steam receiver, the connection being made by means of a pipe. The tubes are placed directly over the fire, a few, however, being placed at the side of the fire, as in the Lagrafel-D'Allest boiler. The tubes are placed in diagonal rows, so that one tube is immediately over the space between the two below it. The products of combustion pass from the fire directly up amongst the tubes, and this arrangement of tubes produces a more efficient action of the hot gases than would result if the tubes were arranged in rows vertically over one another. It will be seen that in the arrangement for the circulation of the furnace gases this boiler is similar to the older form of Lagrafel boiler.

The working water level is some distance below the upper rows of tubes. The circulation takes place within the boiler

itself, being upwards along the lower rows of tubes, into the front water chamber, back along the rows of tubes nearest the water level, down the back chamber, then through the tubes again, and so on. The tubes used are about 2 inches in diameter, and it is stated that the circulation is so rapid that no deposit takes place in them, even if impure water is used.

It will be noticed that several of the tubes are above the working water level, and when working must only contain steam, which, therefore, must become, to some extent, superheated. It is probable that the surfaces of these tubes, having only steam on one side of them, will prove less efficient for absorbing the heat from the furnace gases than the similar surfaces in other boilers which have water in contact with them, and, further, these tubes may be expected to waste much more rapidly than other parts of the boiler.

The Belleville boiler (shown in Fig. 4) consists of a series of sets of tubes placed side by side over the fire and inclosed in non-conducting casings. Each set of tubes, called by the maker "an element," is constructed in the form of a flattened spiral, and consists of a number of straight tubes connected at the ends by means of screwed joints to junction boxes made of malleable cast iron. The junction boxes of each element are placed vertically over one another, and are so constructed that the upper end of one tube is at the same level as the lower end of the next tube in the spiral. The junction boxes at the back end of the elements are close-ended, but those of the front end have holes in them to permit of the inspection of the inside of the tubes, these holes being closed by specially-constructed doors. The examination of the interior of the boiler is made by means of an electric light fixed to the end of a rod which can be inserted in any tube. The tubes used in boilers for war vessels are about 3 inches diameter, while those for merchant vessels are generally about 5 inches diameter. The thickness of the tubes in the latter case is about $\frac{1}{4}$ inch, except the two bottom rows, which are made about $\frac{3}{8}$ inch.

The tubes are all slightly inclined to the horizontal. The lower box of each element is connected by means of a bolted

joint to a horizontal cross tube at the front of the boiler, called a feed collecting tube. Each element is connected also at its upper part by a bolted joint to the lower part of the horizontal steam chest or receiver, which latter is outside the boiler casing. An external pipe connects the bottom of the steam chest with the separating chamber, which again is connected with the horizontal feed-collecting tube. The boiler feed, as delivered by the feed pump, enters the steam chest at the end opposite to that to which the circulating pipe is attached. The working water level in the boiler is a little above the bottom of the steam chest. The circulation takes place by each element receiving a supply of water from the horizontal feed collector into its bottom tube. This water is partly evaporated in the lower tube, and passes partly as steam and partly as water through the back junction box into the tube above it, where a further portion is evaporated, and so on. Each tube, therefore, has to convey all the steam made in those tubes of the same element which are below it, as well as that formed within itself. A mixture of steam and water is thus continuously discharged from each element into the receiver. The water so circulated mixed with the fresh feed water passes along the receiver bottom through the external circulating pipe into the separating chamber, and thence into the horizontal feed collector to be again circulated through the elements.

It will be seen that the tubes nearest the fire, and which therefore are exposed to most heat, contain relatively more water and less steam than those higher up in the boiler. Also, as the circulation depends upon the greater density of the water unmixed with steam in the external circulating pipe as compared with that of the mixture of steam and water in the elements, it follows that the greater is the average quantity of steam as compared with the water in the elements, the more rapid will be the circulation. The fact, therefore, that the whole of the steam formed in the lower tubes has to pass through the upper ones before being delivered into the steam chest, will increase the circulation beyond that which would result if each tube discharged its steam direct into the receiver, as is the case with the boilers previously described. On the other hand, it will be noticed that

the water has to reverse its direction of motion each time it passes out of one tube into another, and this, no doubt, has a retarding effect on its velocity.

The use of the separating chamber is peculiar to this boiler, and, together with the method of feeding, is the outcome of considerable experience. Marine engineers, who are familiar with ordinary boilers fed with water from surface condensers, know how detrimental are the deposits which accumulate on the heating surfaces from the presence of grease and small quantities of sea water in the feed, and some anxiety must be felt on this account in all vessels engaged on long voyages, necessitating the boilers being under steam for very long periods, even when the minimum amount of grease is used for the cylinders, piston rods, &c., and the feed make-up is provided by an evaporator. A slight leak in the condenser, for instance, will contaminate the feed in spite of an evaporator.

In working this boiler the feed water is treated with a small quantity of lime in very dilute solution. It is delivered from the feed pump into the receiver at the end remote from the external circulating tube; it thus has to pass along the whole length of the bottom of the receiver, where it becomes mingled with the mixture of steam and water issuing from the elements. Its temperature must therefore be raised to that of ebullition before it enters the circulating pipe. At this temperature all the lime salts which are contained in the small quantity of sea water which may be mixed with the feed, as well as the lime in solution with which the feed is purposely treated, separate out in a solid but non-crystallizable form, which, being in an extremely fine state of division, is stated to become mixed with the oil particles which may be in the feed water, and to form a kind of mud which separates and falls to the bottom of the separating chamber, owing to the water being comparatively quiescent at that part. The effluent feed water is thus purified before it enters the parts of the boiler comprising the heating surface, which therefore do not become encrusted. Experience shows that this actually takes place to a considerable extent, there being practically no deposit on the heating surfaces, even when sea water make-up is used,

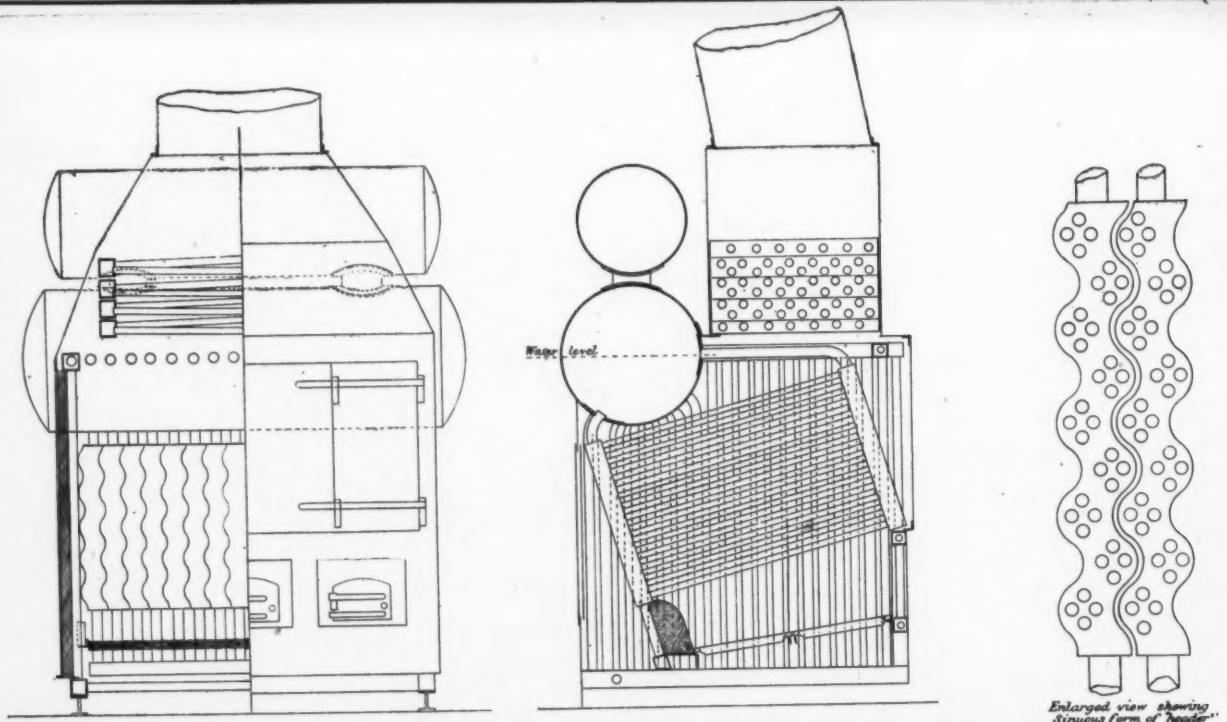
while a white muddy deposit is found in the separating chamber.

It should be mentioned that in working the Lagrafel-D'Allest boiler the feed water is similarly treated with lime, an amount of about 4 pounds per 24 hours per 1,000 I.H.P. being used, an arrangement being adopted whereby this small quantity can be regularly and continuously added to the feed; but in this boiler the separation cannot take place before the entry of the feed amongst the heating surfaces. The deposit takes place mostly in the lower part of the back chamber where the water is quiescent.

It is to be noted that in the Belleville boiler the junctions throughout are made with either bolted or screwed joints, no expanded joints being used. The tubes are simply screwed into the back junction boxes, the joint being secured with a thin checknut. The front junction boxes are fitted with screwed nipples, over which and over the front end of the tube a socket or collar is screwed, the joint being also backed up by a checknut. At this end of the tubes, therefore, a double thickness of metal is exposed between the fire and the water. What will appear as a novelty to English engineers is the use of malleable cast iron for the junction boxes, which are exposed to the same pressure as the rest of the boiler, and also to a considerable amount of heat.

It has been stated that the internal surfaces of the tubes may be examined from the front ends, and they may also be cleaned if necessary. The external surfaces are cleaned by means of a steam jet inserted in the spaces between the junction boxes.

The ease with which repairs to these boilers may be effected is shown from the fact that a boiler may be shut off from the others, emptied, any element disconnected by breaking the upper and lower bolted joints, brought out into the stokehold, and any one tube taken out by cutting through the screwed socket connecting it to the front junction box and unscrewing it from the back box; a new tube and socket can then be inserted, the element replaced, the boiler refilled, and steam again raised in



BABCOCK & WILCOX BOILER.

FIG. 1.

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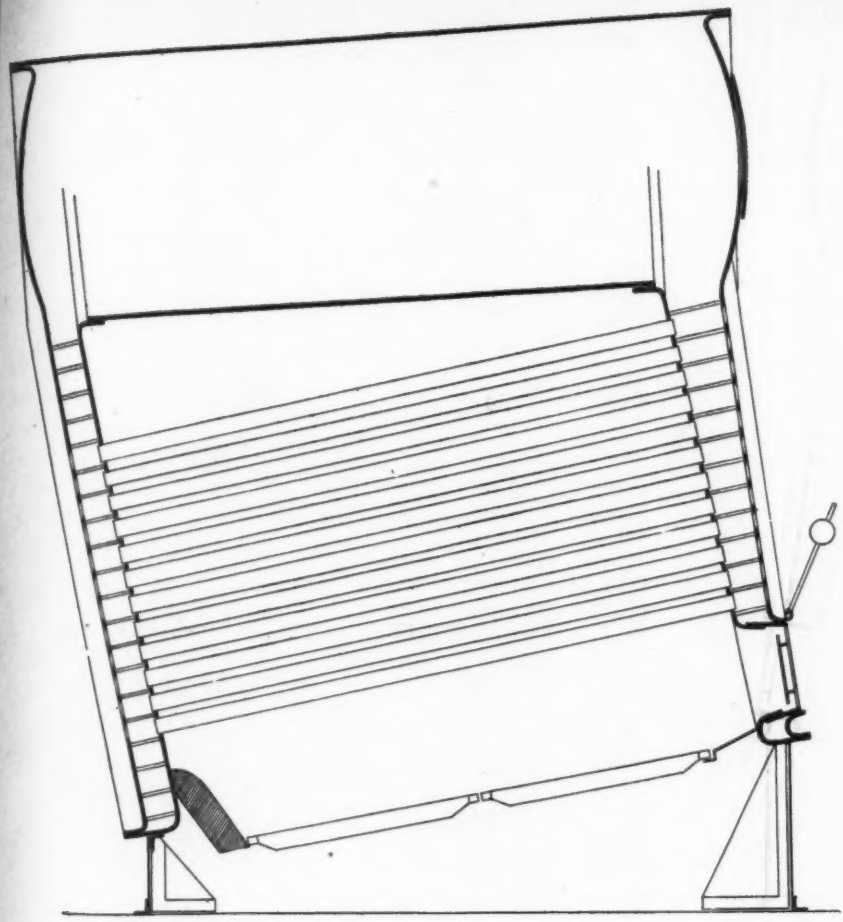
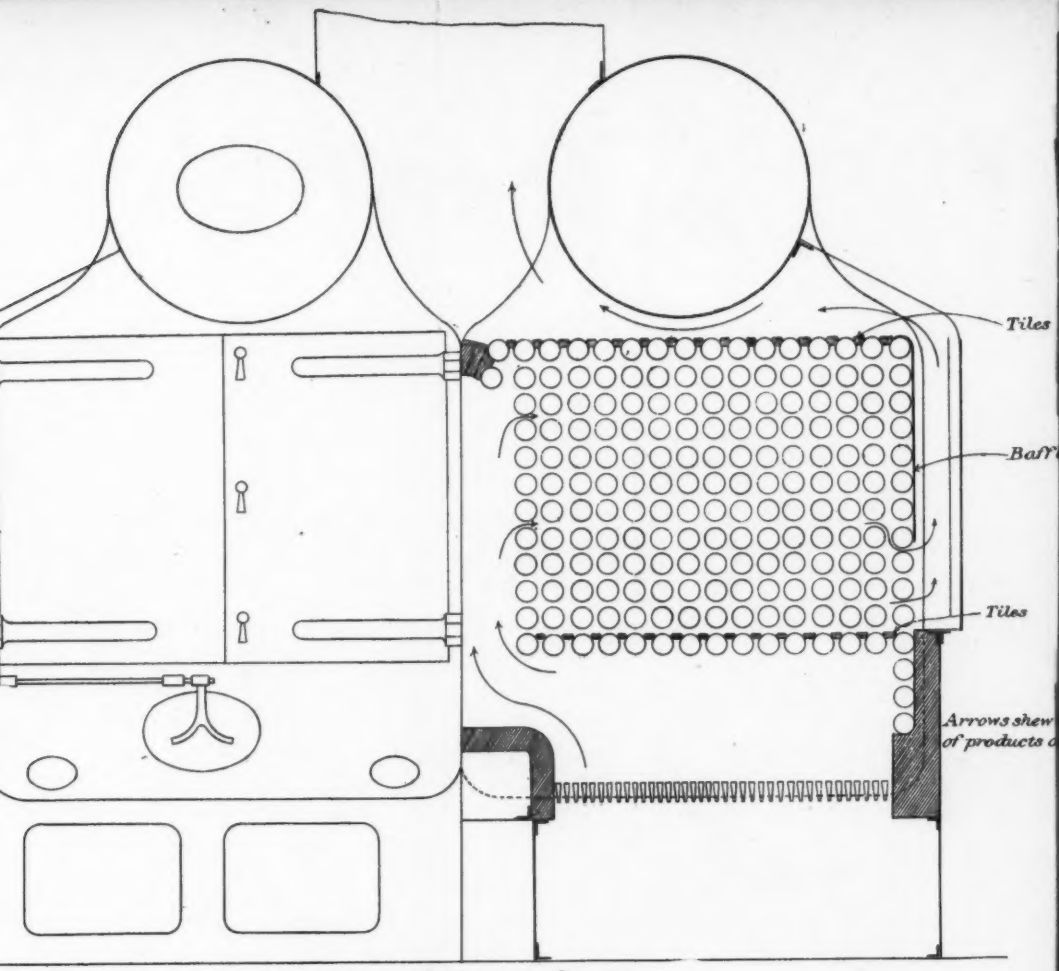


ENLARGED VIEW

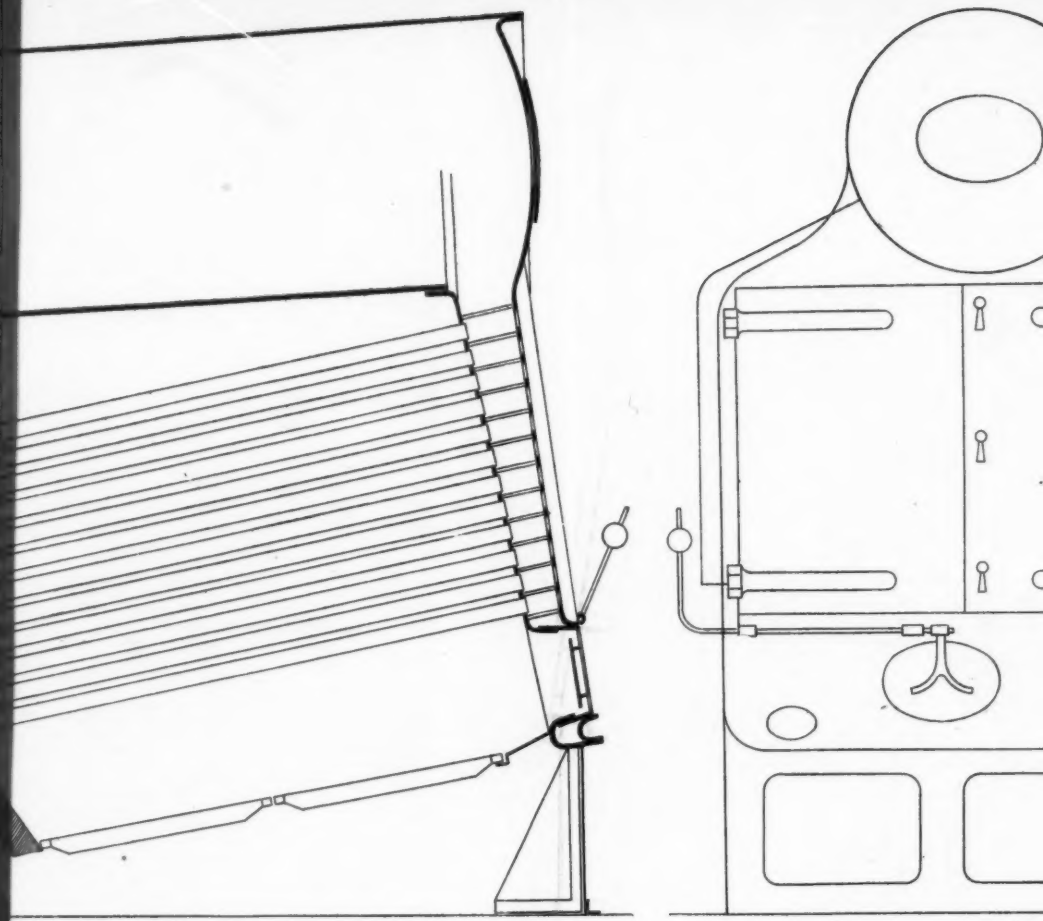
F



LAGRAFEL - D'ALLEST BOILER

W OF TUBES AND TILES.

FIG. 2.



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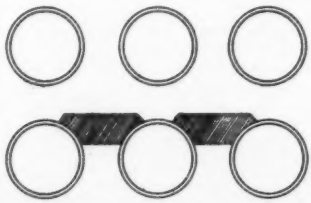
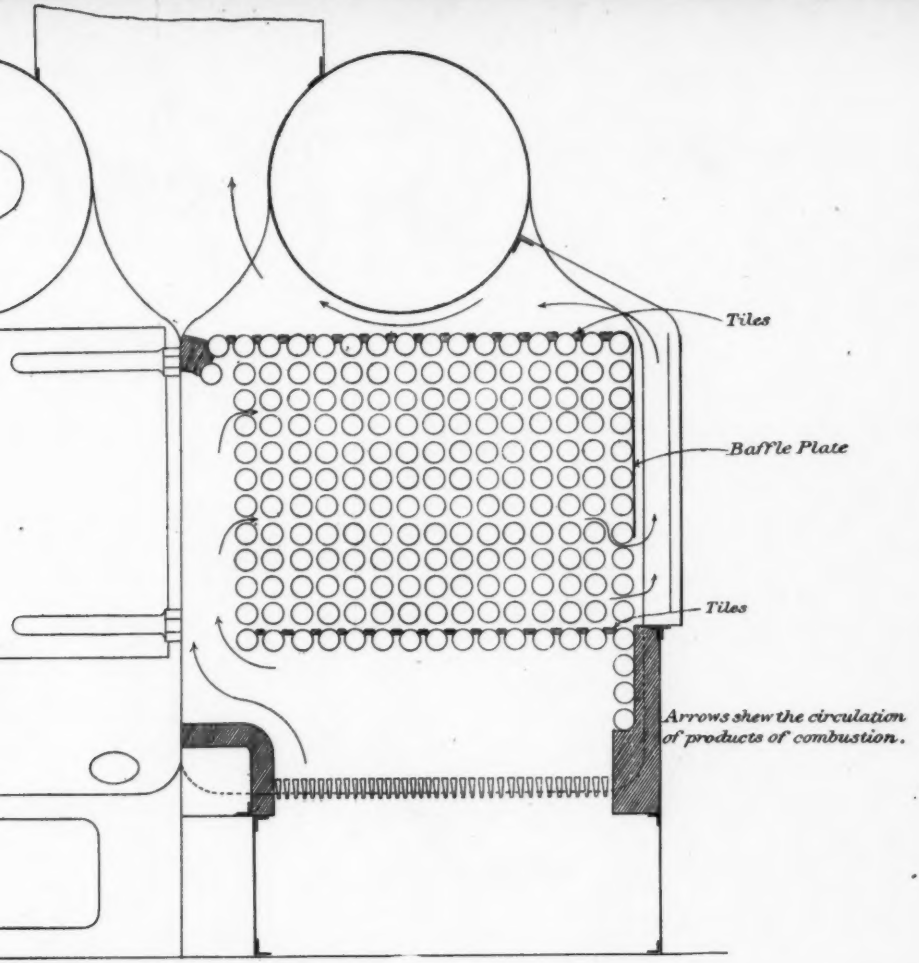


ENLARGED VIEW OF TUBES AND TILES.

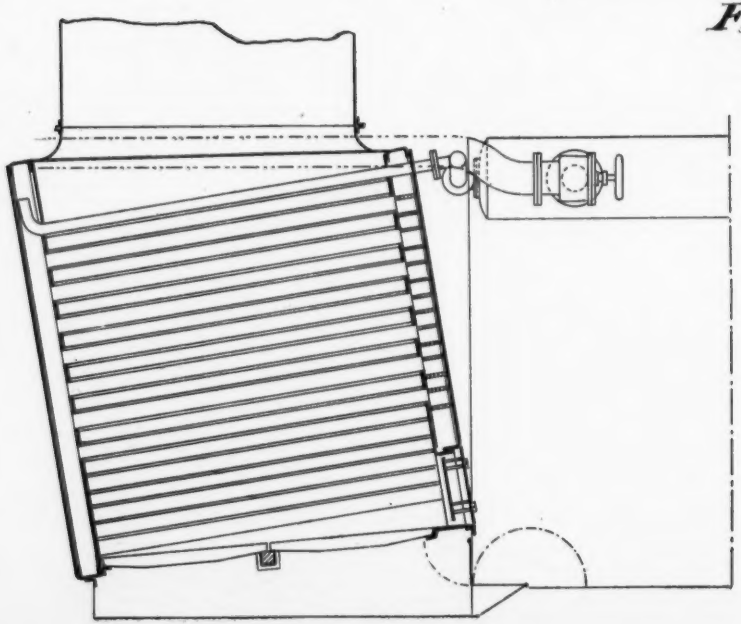
FIG. 2.



LAGRAFEL - D'ALLEST BOILER

Oriolle Tubulous Boiler.

Fig. 3.



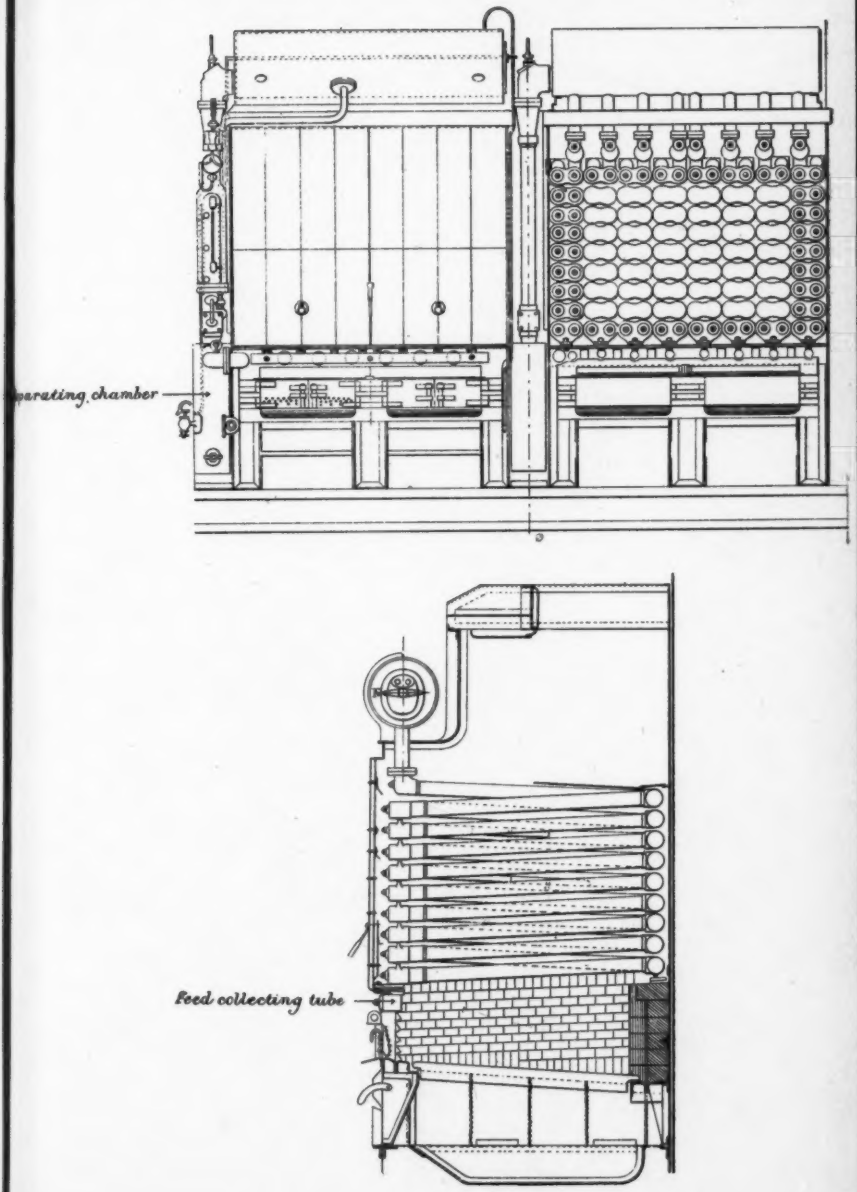
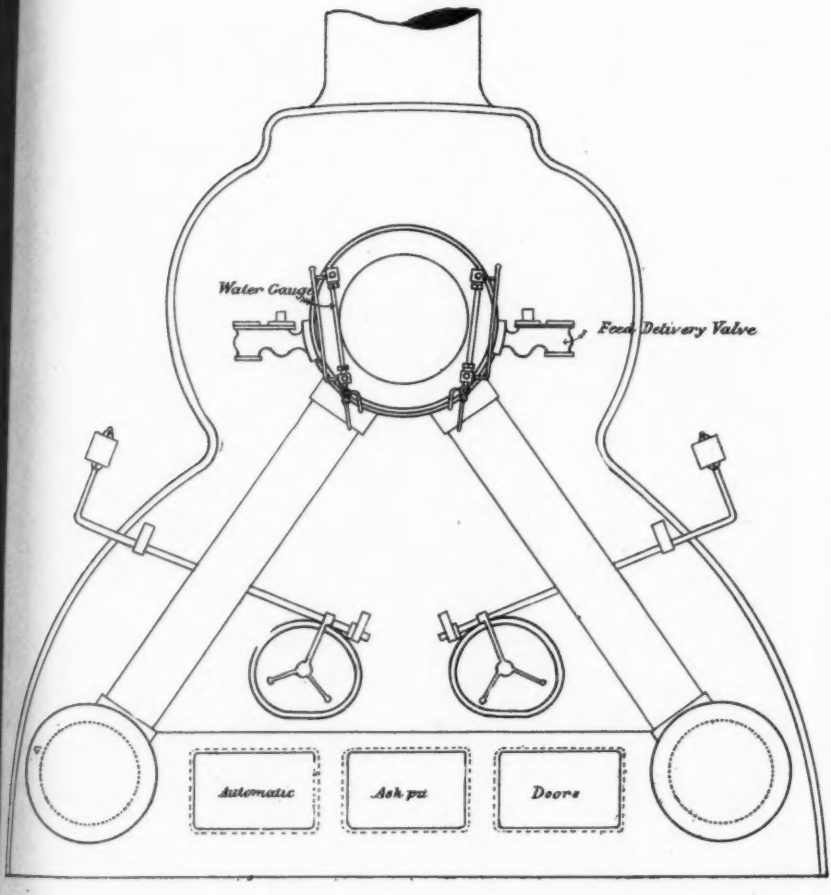


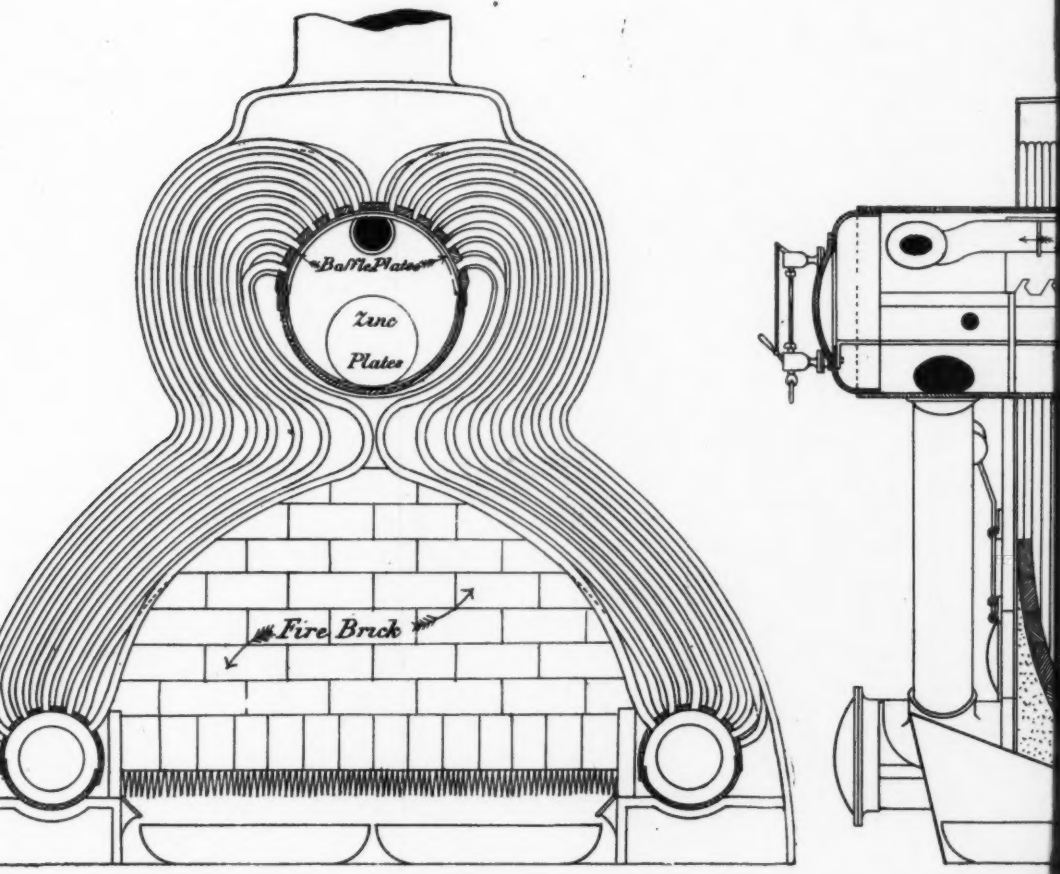
FIG. 4.

XL

THE "

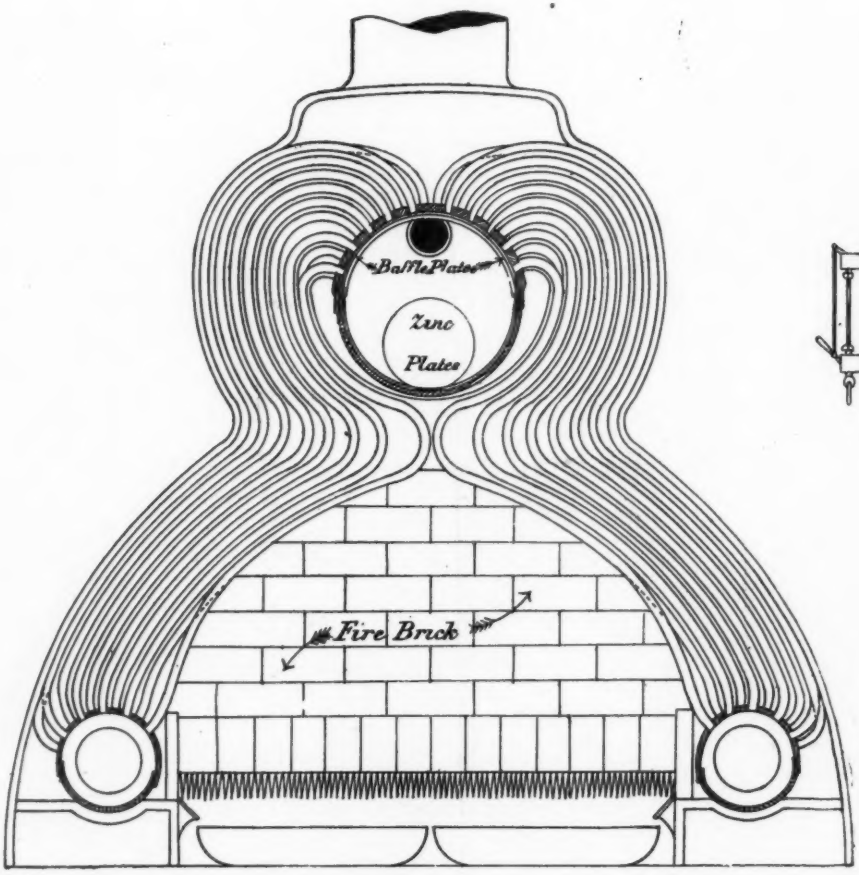


"THORNYCROFT" WATER TUBE BOILER.



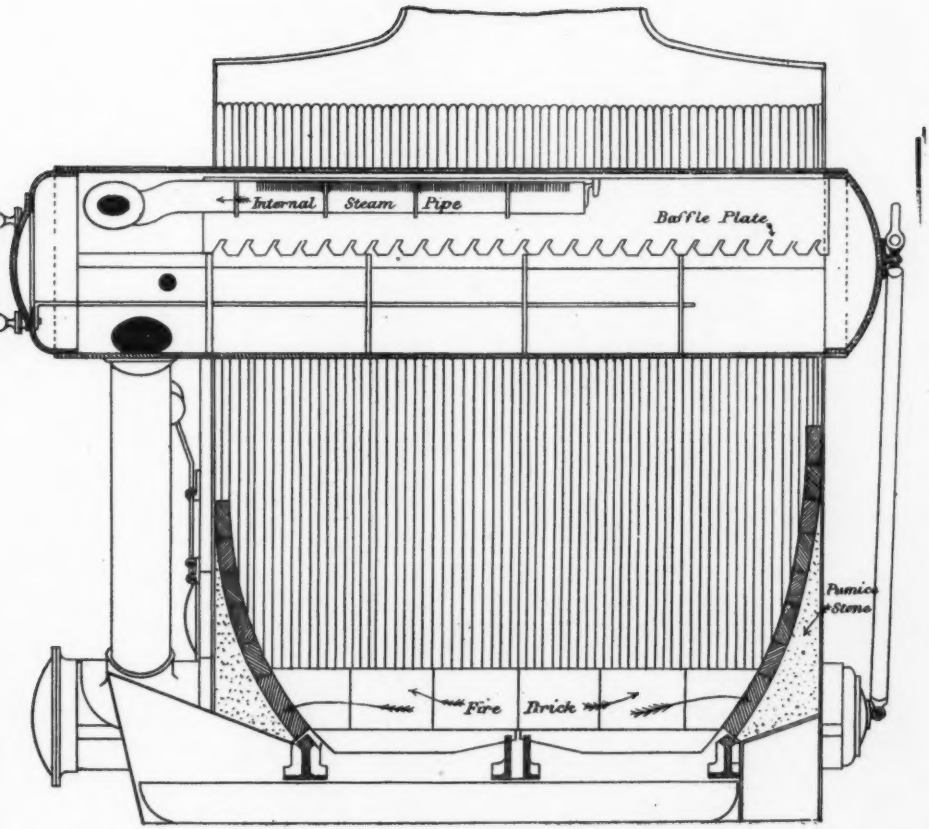
— Fig. 5. —

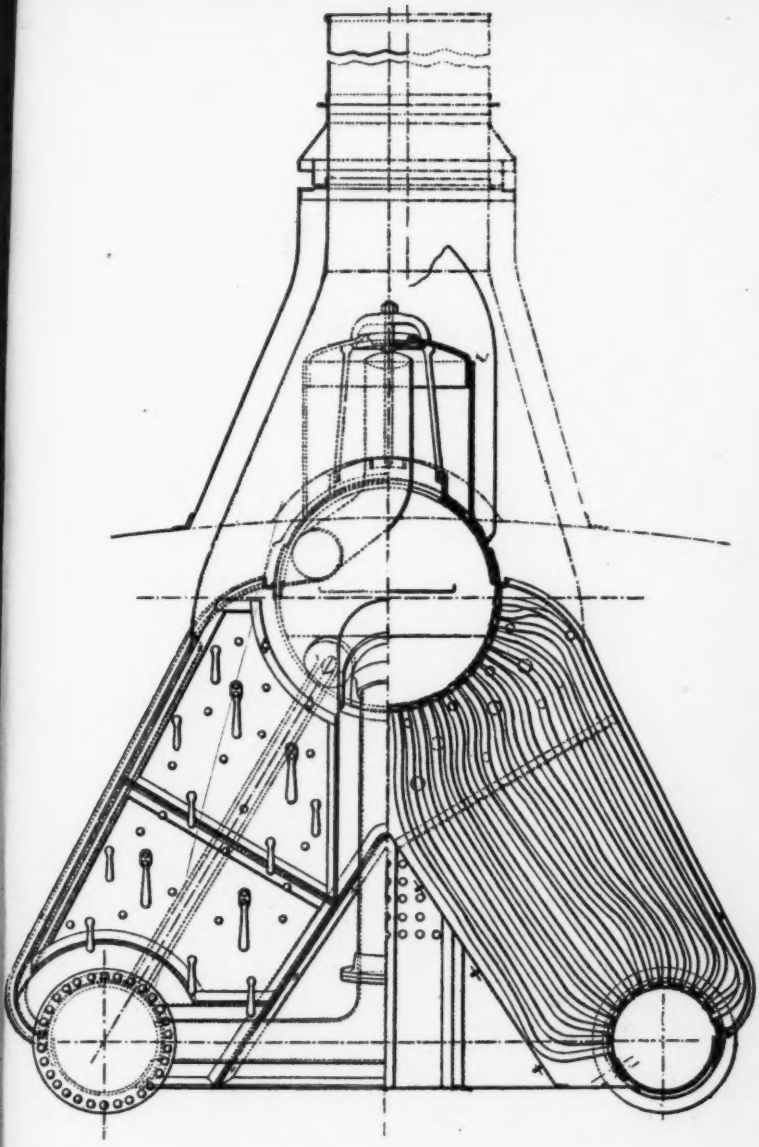
THE "THORNYCROFT" WATER TUBE BOI



— Fig. 5. —

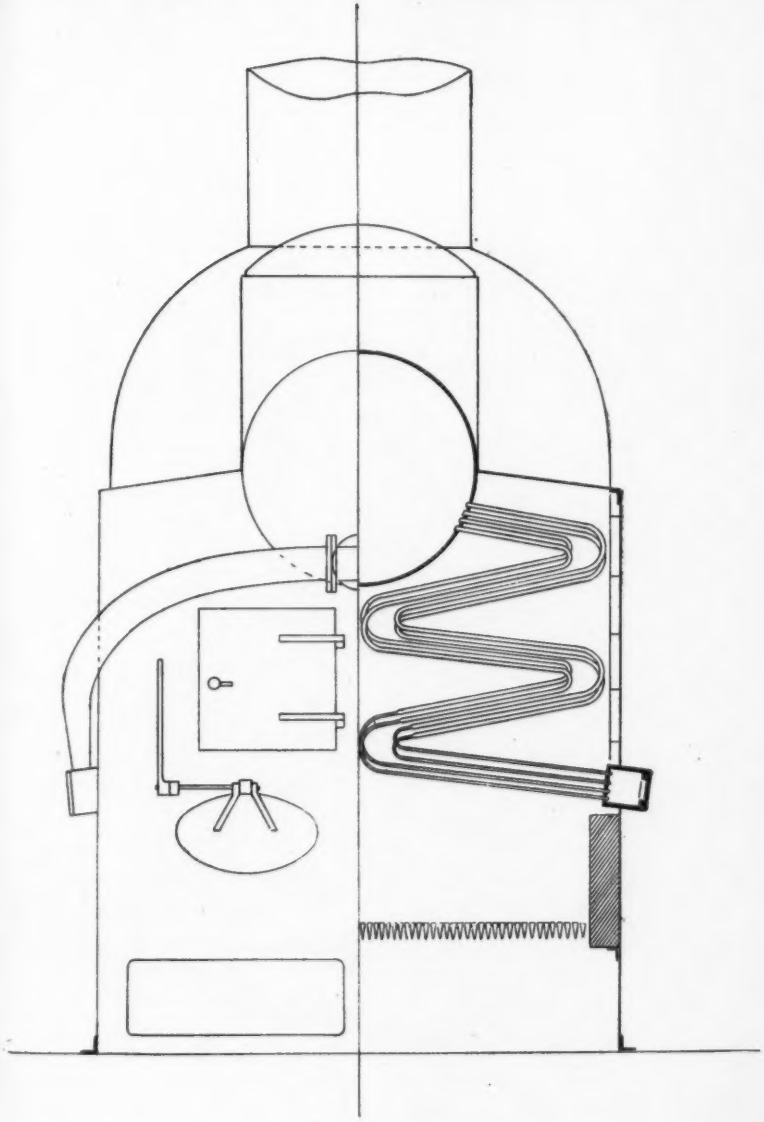
ILER.





NORMAND BOILER.

FIG. 6.



DU TEMPLE BOILER.

FIG. 7.

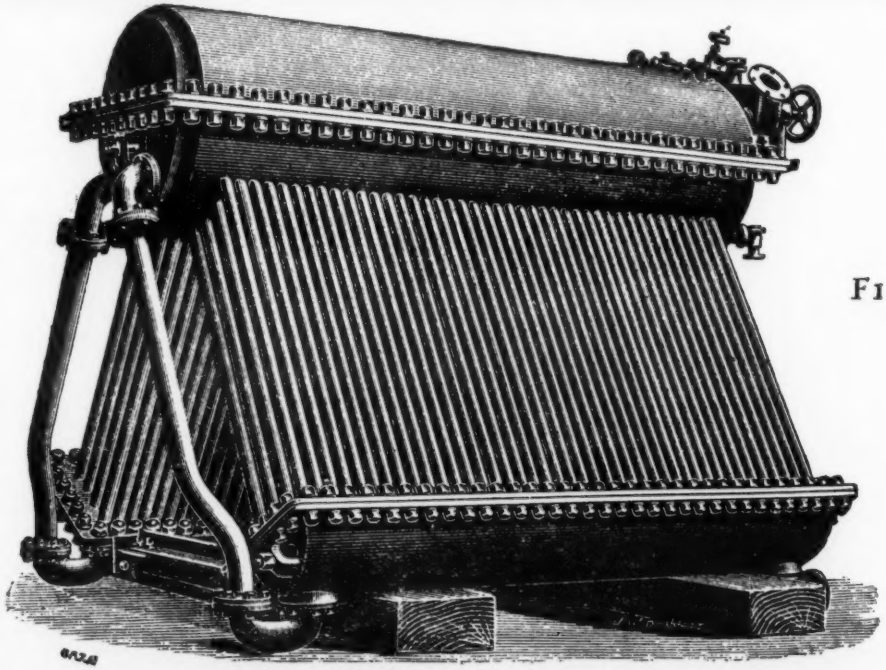


FIG. 9.

Yarrow's Tubulous Boiler.

about six hours, the whole work being done by one skilled engineer, assisted by firemen.

It will be noticed that the boilers previously described are composed of straight tubes of comparatively large diameter, the designs admitting of more or less perfect inspection and cleaning of the whole of the internal surfaces. Those remaining to be described are in marked contrast, being composed of small tubes in proportion to their length, and in only one out of the four are the tubes straight, in the other three neither inspection nor cleaning of the internal surfaces being practicable.

The Thornycroft boiler was fully described by Mr. Thornycroft at the spring meeting of this Institution in 1889. Fig. 5, representing the boiler, is reproduced from the Transactions of that year. It consists mainly of three horizontal cylinders, the upper one being the steam chest. The upper is connected to the two lower chests by two circulating tubes of large size, external to the boiler casing, and by a multitude of small tubes bent into tortuous curves within the casing, these small tubes forming the heating surfaces. In the external rows these tubes are placed side by side in contact, in order to protect the casing, while the inner rows are similarly placed side by side to form a continuous arch over the fire, and to compel the products of combustion to pass uniformly around the other tubes forming the heating surfaces. A peculiarity of this boiler is that all the tubes enter the upper half of the steam chest. The tubes are 1 inch and 1¼ inches in diameter. The working water level is such as to permit the upper chest to contain a considerable quantity of water. The tubes being so small in diameter, the evaporation in them renders the density of the mixture of water and steam they contain so much less than that of the water, which is without admixture of steam, in the external circulating pipe, as to cause a rapid circulation even through the upper or highest tubes. The water brought over by the tubes is separated from the steam by means of the baffle plates.

The products of combustion enter the lower parts of the spaces between the tubes and traverse nearly the whole length of the tubes in the direction of their length. It is difficult to see how the

outside of the tubes can be freed from soot and the lower parts of the spaces between the tubes from an accumulation of ashes and dust. These points, combined with the impossibility of examining them internally and the difficulty of localizing any tube which may become defective, and of renewing it when discovered, will, it is thought, prevent the introduction of this boiler for use in ocean-going steamers, but the results obtained by it as regards its evaporative power in proportion to its weight, combined with its evaporative economy in proportion to the fuel consumed, show how eminently suitable it is for purposes where enormous power is of more consequence than very prolonged efficiency. Particulars of these results may be found in the references quoted, and also in Mr. Thornycroft's paper read at the Institution of Civil Engineers.

A modified form of this boiler, containing two fire grates, has been proposed by Mr. Thornycroft, in which there are one upper or steam chamber and three lower water chambers, the center and largest of these being between the two fire-grates.

Fig. 6, reproduced from "The Engineer" of July 15, 1892, represents a cross section of the Normand boiler, which is seen to present some of the features of the Thornycroft boiler. There are the same three horizontal cylindrical receivers, the upper being a steam chest and the two lower being water chambers, the main point of difference being that all the heating tubes are connected to the lower half of the steam chest instead of to the upper half. There are in this boiler external circulating tubes placed at both ends instead of at one end only, as in the Thornycroft boiler. A reference to the sketch will show that, while the shapes of the heating tubes are different from those in the other boilers, considerable trouble appears to have been taken to prevent any of them from being straight.

Fig. 7 shows a cross section, &c., of the Du Temple boiler, as fitted in torpedo boats. This also bears some resemblance to the two former boilers, but there are some important differences. Like the Normand boiler, there are two external circulating tubes at each end connecting the upper with the lower chambers, and the heating tubes also enter the upper chamber along

the bottom half. These heating tubes are of small diameter, and of the zigzag shape shown, and have the peculiarity of having their lower portions made of reduced diameter. The water chambers are made of comparatively small cross section, but they are fitted throughout their length with doors, which give access to their interiors. The fire grate is situated between brick sides, so that the whole of the length of the heating tubes is above the level of the fire. The products of combustion rise straight up from the fire between the tubes, so that the direction of motion of the gases is across the length of the tubes instead of along it, as in the Thornycroft boiler.

The Yarrow boiler is represented by Fig. 9, which is reproduced from "Engineering" of January 16, 1891. In this boiler also there are one upper and two lower horizontal chambers, connected by two circulating tubes external to the casing, and by a number of small heating tubes which, in this case, are straight. In the smaller boilers the upper chamber is made in two halves, bolted together, to enable the upper half to be removed. The lower chambers are each made with a flat side, forming a tube plate, the lower portions being of semi-cylindrical form, bolted to the tube plates. By removing these parts the tubes are accessible from both ends, and, being straight, they may be examined and cleaned as well as their small diameter will permit. The outside of all the tubes also may be cleaned from soot, etc., the casing being made portable to permit of this. The fire grate is placed between the lower chambers, and the products of combustion pass between the tubes on their way to the chimney, their direction of motion being across the length of the tubes, as is the case in the Du Temple boiler.

In both the Yarrow and Thornycroft boilers the heating tubes are made of seamless steel. In some cases they have been galvanized. Seamless tubes are used, not so much on account of their strength being greater than that of lap-welded tubes of the same diameter and thickness, as to ensure freedom from small local defects in the weld, which, although not materially impairing the strength, may, by reason of the less thickness of sound metal they present, permit a small amount of corrosion to per-

forate the tube, in which, of course, even a minute pinhole, permitting the escape of steam or water, will necessitate the removal of the tube.

A combination of water-tube and ordinary smoke-tube boiler is now being tried by Messrs. Anderson & Lyall, of Glasgow. In this boiler the water tubes are placed over the fire, and re-receive the fullest heat of the products of combustion, which, after entering a combustion chamber, pass through the smoke tubes which are surrounded by water. In this form of boiler the ordinary furnace flue is dispensed with, and the casing of the part of the boiler containing the tubes is of considerably smaller diameter than the shell of an ordinary boiler containing the same heating surfaces, so that thinner plates and less weight both of boiler and water are needed. The makers have at present only made one boiler on this plan, and they are now engaged in making experiments with it to determine the most advantageous proportions for the various parts with the view of adopting the plan for marine purposes.

The experiences given in the paper as to the time during which some of the boilers have been in use, and the fact that their use is extending amongst those most familiar with them, show that so far as safety is concerned water-tube boilers can be made satisfactory. The point upon which many will wish for information is that of their economy as steam raisers on ordinary service. Unfortunately I am unable to supply this information.

In the paper to which reference has been made, however, some information will be found as to the efficiency of the Thornycroft boiler, and I am indebted to Mons. D'Allest for some information given in the Appendix as to the results of trials made upon the Lagrafel and Lagrafel-D'Allest boilers by Mons. Taton, a French naval engineer.

In each case of these trials the coal used was carefully weighed, the firing being regulated to burn 50, 75, 125 and 150 kilos per hour per square meter of the grate area. The feed water was measured, and it was noted that there was practically no water (priming) carried off with the escaping steam. The

results with the modern form of the boiler show a very good efficiency, and if such results can be obtained in ordinary working with water-tube boilers, the higher pressures they will admit of should lead to more economical results being obtained.

RESULTS OF EXPERIMENTS MADE WITH LAGRAFEL-D'ALLEST BOILERS UNDER THE DIRECTION OF FRENCH NAVAL OFFICERS, AND OF REPRESENTATIVES OF THE FORGES ET CHANTIERS DE LA MÉDITERRANÉE.

	Trial No. 1.	Trial No. 2.	Trial No. 3.
Date of trial	June 29, 1892.	July 2, 1892.	July 6, 1892.
Duration of trial	6 hours.	12 hours.	6 hours, total.
Weight of Cardiff coal burned during the trial	4,500 kilos.	5,400 kilos.	2,700 kilos., 1st 3 hours. 3,375 " 2d "
Do. per square meter of grate per hour	100 kilos.	60 kilos.	120 " 1st " 150 " 2d "
Water evaporated during the trial	44,125 liters.	54,370 liters.	25,654 liters, 1st " 31,169 " 2d "
Do. per hour	7,354 liters.	4,530 liters.	8,551 " 1st " 10,389 " 2d "
Do. per square meter of heating surface	29.41 liters.	18.12 liters.	34.2 " 1st " 41.55 " 2d "
Do. per kilo. of coal	9.80 liters.	10.068 liters.	9.501 " 1st " 9.235 " 2d "
Temperature of feed	48.75° C. = 119.75° F.	51° C. = 123.8° F.	52° C. = 125.6° F. mean during both periods.
Do. of evaporation	194° C. = 381° F.	194° C. = 381° F.	194° C. = 381° F.
Evaporation from and at 212° F.	11.25	11.51	10.85 during 1st 3 hours. 10.54 during 2d 3 hours.

RESULTS OF SIMILAR TRIALS ON ANOTHER VESSEL.

	February 12, 1890.	February 19, 1890.	February 25, 1890.
Date of trials			
Duration of trials	3 hours.	3 hours.	8 hours.
Coal burned per sq. meter of grate surface per hr.	223.4 kilos.	175 kilos.	75 kilos.
Water evaporated per kilo. of coal	8.24 kilos.	9 07 kilos.	9.43 kilos.

RESULTS OF OFFICIAL TRIALS OF S.S. *LIBAN*, MADE IN OCTOBER 1890, WITH SPEED OF ENGINES VARIED IN ACCORDANCE WITH THE POWERS DEVELOPED.

Duration of trials	8 hours.	24 hours.	8 hours.	8½ hours.
I.H.P. per square meter of grate (French measures)	66.1	86.2	132.9	147
Do. per square foot of grate (English measures)	6.06	7.9	12.1	13.45
Coal per I.H.P. (French) per hour	.614 kilos.	.667 kilos.	.732 kilos.	.808 kilos.
Do. per I.H.P. (English)	1.37 pounds.	1.49 pounds.	1.63 pounds.	1.8 pounds.

APPENDIX.

RESULTS OF EXPERIMENTS MADE AT MARSEILLES WITH LAGRAFEL AND LAGRAFEL-D'ALLEST BOILERS, UNDER THE DIRECTION OF MONS. TATON, ENGINEER OF THE FRENCH NAVY.

PARTICULARS OF BOILERS.

LAGRAFEL-D'ALLEST BOILERS.

	Trials Nos. 1, 3, 5 and 6.	Trial No. 2.	Trial No. 4.
Grate surface	3.3 sq. meters. =35.9 sq. feet.	2.86 sq. meters. =30.8 sq. feet.	4. sq. meters. =43. sq. feet.
Proportion of heating to grate surface	30	35	25
Tubular surface	96.7 sq. meters = 1,040. sq. feet.		
Plate heating surface	3.3 sq. meters = 35.5 sq. feet.		
Total heating surface	100. sq. meters = 1,076. sq feet.		
Section of chimney	.95 sq. meters = 10.2 sq. feet.		

LAGRAFEL BOILER.

Grate surface	3.3	sq. meters =	35.5 sq. feet.
Tubular surface	96.7	sq. meters =	1,040. sq. feet.
Plate heating surface	3.3	sq. meters =	35.5 sq. feet.
Total heating surface	100.	sq. meters =	1,076. sq. feet.
Section of chimney	.95	sq. meters =	10.2 sq. feet.
Proportion of heating to grate surface			30

Trials Nos. 1, 2, 3 and 4 made with the Lagrafel-D'Allest boilers, and Nos. 7, 8 and 9 with the Lagrafel boilers, were made with natural draft. Nos. 5 and 6, with Lagrafel-D'Allest boilers with forced draft.

	Lagrafel-d'Allest Boilers.						Lagrafel Boilers.		
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.
Duration of trial.....hours...	6.	6¾	6.	6.	3.	3.	6.	3.	3.
Weight of Cardiff coal burned during the trial.....kilos...	1,008.	1,430.	1,512.	1,800.	1,224.	1,512.	1,512.	756.	1,008.
Weight of Cardiff coal burned per hour.....kilos...	168.	211.8	252.	300.	408.	504.	252.	252.	336.
Weight of Cardiff coal burned per sq. meter of grate per hour..kilos...	50.45	74.	75.67	75.	122.5	151.35	75.7	75.7	100.9
Weight of ashes, &c.....kilos...	80.	121.5	233.	153.	104.	128.7	...	...	...
Water evaporated during the trial, liters...	10,760.	13,700.	13,970.	16,150.	9,820.	13,230.	10,170.	4,110.	6,580.
Water evaporated per hour...liters...	1,793.	2,029.6	2,328.3	2,691.6	3,273.3	4.410.	1,695.	1,370.	2,193.3
Water evaporated per square meter of heating surface.....liters...	17.93	20.29	23.28	26.91	32.73	44.1	16.95	13.7	21.9
Water evaporated per kilo of coal, liters...	10.67	9.58	9.23	8.97	8.02	8.75	6.72	5.43	6.526
	C. F.	C. F.	C. F.	C. F.	C. F.	C. F.	C. F.	C. F.	C. F.
Temperature of feed.....degrees...	25=77	25=77	21.5=70.7	27=80.6	20.5=68.9	21=69.8	22=71.6	22.5=72.5	23=73.4
Temperature of evaporation....deg...	148=298	148=298	148=298	148=298	148=298	148=298	148=298	148=298	148=298
Evaporation from and at 212 degrees..	12.43	11.14	10.8	10.4	9.4	10.24	77.8	6.34	7.62

Discussion.

[Reprinted from "Engineering."]

Mr. Yarrow said that the institution was under great obligation to Mr. Milton for having collected together so much valuable matter, and for having so ably dealt with a subject which must be looked upon as among the most pressing of the day. Engineers had been forced to the conviction that if pressures increase in the future as they have done in the past, there would be no option left but to abandon old forms of boilers in favor of the water-tube type, which is specially adapted to meet the requirements of high pressures. Mr. Milton in his paper had brought forward numerous very interesting facts, and many members of the institution doubtless had been surprised at the already extensive employment of water-tube boilers abroad. It would seem that this particular advance had been greatly promoted in France, owing to the fatherly care of the Government over the lives of the people; as in the case of stationary boilers the law there practically prohibited the use of any but water-tube boilers. Any one who had devoted attention to the subject could not fail to be more or less perplexed by the variety of design, more particularly in France and the United States, but there were distinguishing features which enabled them to be placed in well-defined groups: for example the Belleville boiler might be looked upon as representing one of the types in which the circulation takes a very long and sinuous course, the water and steam ascending from the lower to the upper part of the boiler, having to pass through pipes first in one direction and then in another. As the circulation is dependent partly upon the difference in the specific gravity of the ascending and descending columns, and partly upon the resistance offered to the circulation, due to the friction of the water in the tubes, it followed that those designs which involve a long and tortuous passage for the water and steam are only adapted for moderate rates of combustion. On the other hand, to suit a very intense rate of combustion, the passage of the water from the lower to

the upper part of the boiler should be as short, direct, and free from resistance as possible, such, for example, as in Normand's boiler, which in this respect had, the speaker said, a decided superiority over many others. In fact, he did not think it would be far wrong, when comparing designs of water-tube boilers, to come to the conclusion that the rate of combustion for which they are adapted is in proportion to the simplicity and directness of the circulation, and that the more nearly the tubes approached the vertical, the more suited they were to withstand considerable forced draft.

There was a very marked difference in the designs of water-tube boilers, as regards the amount of elasticity and freedom to move of the various parts. In the D'Allest, Oriolle, and Yarrow boilers the tubes were straight and rigidly secured at both ends, while, on the other hand, in the Thornycroft, Belleville, and Babcock and Wilcox boilers considerable liberty of movement was allowed to each tube or set of tubes. It would seem correct for the tubes to be free to contract and expand as circumstances required; at the same time it might be a question whether, with rigidly fixed tubes, their own elasticity was not sufficient to allow for the necessary changes: experience alone could determine this point; but it was known that in locomotive and marine boilers no practical objection had been found to tubes being straight, although not all subject to the same temperature. Touching the question of economy, judging only by the experience of the speaker's firm, with equal weights of boilers developing the same power, the locomotive and water-tube boilers had been found to be on an equality; but by substituting for a locomotive boiler (which, if well-designed, was economical) one of equal power of the water-tube type, there was saved in weight about 15 per cent., at the same time causing an increase in the consumption of fuel of about 10 per cent. These figures only applied when a maximum amount of forcing was carried out, but not when moderate forcing was adopted, in which latter case the economy of the water-tube boiler is greatly augmented, and under these conditions it occupies a much more favorable position, perhaps even better than the locomotive. In other words,

with equal forcing, the two types of boilers, if of equal weight, have the same economy, but the water-tube boiler, if required, can be forced to a greater extent.

One difficulty to be met with in the introduction of water-tube boilers had been the rapid pitting which occurred when steel or iron tubes were used. Even galvanizing only postpones but does not avoid this. M. Normand, as well as the speaker's firm, frequently adopted copper tubes, and, although there was insufficient experience to enable a decided opinion to be expressed, there seemed reasonable probability that copper tubes would have a decided advantage over those of steel as regards durability, provided the design of the boiler was such that the tubes could not become overheated. Mr. Yarrow wished to say that, in the introduction of water-tube boilers, M. Normand was, as usual, well to the front; and he thought he was only expressing the feeling of the Institution when he said that it was a source of regret that the latter gentleman did not favor the meetings occasionally with his presence, for one who occupied so distinguished a position in the profession would be a most welcome guest.

Mr. Sydney W. Barnaby was the next speaker. He said that, valuable as was the information given in the paper concerning the principal features of a number of different types of water-tube boilers, he ventured to think that what was most worthy of note was the evidence it afforded of the great advance which the water-tube boiler had made in public opinion since Mr. Thornycroft read the paper on "Water-Tube Boilers for War Ships" in 1889, which had been alluded to by Mr. Milton. At that time any proposal to introduce them either into war vessels or the merchant service was regarded with disfavor in this country. They were then considered as suitable for torpedo boats, but for them alone. Mr. Milton's predecessor, with the memory of the failure of the earlier types of water-tube boilers vividly before him, strenuously resisted any attempt to reintroduce a type associated in his mind only with disaster. Mr. Milton was now wisely content to pass over these old failures, and,

recognizing that the lessons taught by them had been duly taken to heart by the designers, or some of them at least, of the modern types, had given them all his very careful attention, and his views were worthy of great respect. The fact that all French war vessels now building and those which had been lately finished were, or would be, furnished with water-tube boilers, showed the extent of the favor accorded to them in France. There were at the present time fitted in vessels afloat or building boilers of the Thornycroft type representing more than 70,000 indicated horse power. This, he thought, compared well with the record of any other water-tube type.

No doubt many of the difficulties connected with the safe working of water-tube boilers had disappeared since it became possible to rely upon the use of distilled water under ordinary conditions. Still, although the greater part of the salts in solution in the make-up feed water were now deposited in the distilling apparatus, it was necessary to provide against the contingency that some amount of sea water would probably find its way into the boiler through leaks in the condenser, and that it might become necessary at times to make up from the sea. They had always looked upon it as very important that the feed should be delivered into the upper part of the boiler when the heat was sufficient to immediately separate the salts. When this was done, their experience was similar to that described in connection with the Belleville boiler, in which he believed this method of introducing the feed had been recently adopted, namely, that the salts were not deposited in the small tubes, which were kept clear by the circulation, but found their way into the bottom tubes, where the water was quietest, and from which they could be readily removed. There was one remark in the paper in regard to circulation which he thought was not quite correct, namely, that the circulation in the Belleville boiler must be greater than in those in which each tube discharged its steam into the separator. The author stated that the greater the average quantity of steam, as compared with the water in the generating tubes, the more rapid would be the circulation. It was obvious that there must be a limit to this, as, when all

the steam generated in the bottom tubes had to escape through those above, the upper tubes might become full of steam only, in which case, as in the Perkins boiler, there was no circulation of water.

Mr. Thornycroft showed in his paper on boilers, read at the Institution of Civil Engineers, that the maximum circulation of water took place when the density of mixed steam and water in the tubes was about one-half that of water. Mr. Milton had said that few boilers became worn-out in less than ten or twelve years, and that he knew of many in use after twenty years' service. These boilers had probably had more than one set of tubes during their lifetime, as he (Mr. Barnaby) believed the life of tubes was not more than from four to six years, at least in locomotive boilers, and it should be remembered that a new set of tubes made a water-tube boiler as good as new.

Mr. Barnaby quite agreed with the author that when the gases were passed directly among the tubes they were cooled too soon, and imperfect combustion must result. He thought the large fire box in the Thornycroft boiler had much to do with the high efficiency obtained. When burning 30 pounds per foot of grate, the evaporation was as much as 12 pounds of water per pound of coal, while at a low rate of combustion it rose to 13.4 pounds. Mr. Milton, in his paper had expressed a doubt as to whether the lower parts of the spaces between the tubes could be freed from ashes and the outside of the tubes from soot. In H.M.S. *Speedy*, in which there were eight boilers, they were so arranged that it was possible to walk round each boiler. Along the whole length of the lower tubes, where dust and ashes would accumulate, were placed portable collecting boxes, which could be readily cleared. They adopted the same plan for cleaning the outside of the tubes as that which he believed was employed in the case of the Belleville boiler, namely, a steam jet which was played among them by means of a flexible hose. The new type of Thornycroft boiler with two furnaces was being employed in the 27-knot destroyers, the principal advantage being that it enabled three boilers to be used in place of six.

Mr. W. J. Pratten next spoke as to the Belleville boiler. He had made two trips on a steamer fitted with this generator, and was much impressed with the fact that the French engineers had shown us the way in the fitting of water-tube boilers. He thought, however, now that we had been shown the way, we should soon get ahead, and in return might teach foreign engineers something. In the *Polynesia*—a ship in which he had made a trip—there were twenty boilers, but if this number were multiplied by five, as they would have to be in the case of a large Atlantic liner, he thought a most important difficulty would arise, in the necessity of having so many sets of fittings, such as water gauges, stop valves, &c. The French officials said that the water-tube boiler was as economical as the shell boiler for ordinary work. If that was the most that could be claimed, he did not think that the cargo tramp would be likely to take them up, but the water-tube boiler was good for the navy and for fast passenger service.

Mr. Josiah MacGregor, of London, thought that it would have added to the value of the paper if the author had dwelt on some of the early experiences with water-tube boilers in this country. In the years 1850 to 1860 a number of boilers of the water-tube type were brought out and tried. He would refer to Rowan's boiler, the Howard boiler, &c., which had passed under his care, although he was obliged to confess that the experience then was not satisfactory.

Dr. White referred to the passage in Mr. Yarrow's speech in which he said that "with equal force, the two types of boilers, if of equal weight, have the same economy." The speaker thought that the opinion here expressed did not square with general experience. Mr. Thornycroft claimed for his boiler that with an equal fuel consumption to that of the locomotive boiler there was an economy in weight, and in the former the fuel economy was very good; in fact, Mr. Thornycroft claimed that with moderate forcing of the combustion he got results equal to those reached with strong forcing in the locomotive boiler, so far as the matter of weight is concerned. The paper to which the meeting had just listened was the best collection of facts up to

that date, in regard to the subject of water-tube boilers, and so far as our language was concerned, but in France there was a literature on the subject which was, no doubt, well known to most of those present. The Admiralty had evinced the greatest interest in this subject from the first; for no sooner did Mr. Thornycroft bring forward his design than it was put in a small torpedo boat.

As other boilers came forward they were to be considered, and trials were to be made of different types on a practical scale, The Admiralty had considered it desirable to attack the question from the small end. They had first put a water-tube boiler in a second-class torpedo boat, then in a first-class boat, and now the *Speedy*, a torpedo gunboat, was being brought forward as fast as possible, and it was expected that her eight boilers would generate steam to the extent of about 5,000 indicated horse power. The experiments would be watched with the greatest interest and might lead to important results. There were also being constructed for the Royal Navy torpedo-boat destroyers in which three types of water-tube boilers were being tried; two at Yarrow's works, and one at Thornycroft's. Arrangements were also in progress to try the Belleville boiler on the same scale as the Thornycroft boiler in the *Speedy*. The DuTemple boiler was also to be put on a similar footing. French engineers would therefore have the satisfaction of seeing their inventions tried in the British Navy, side by side with English boilers. He desired to take that opportunity of expressing his appreciation of the courtesy shown by French engineers to those who were inquiring into this subject. Any facts that were possessed by these gentlemen were put at his disposal with an absence of reserve that he considered beyond all praise. He would especially instance the courtesy of the Messageries Maritimes, in allowing a British naval engineer to take passage in one of their ships and see the working of their boilers. He thought, however, that if the French had taken the lead in working groups of water-tube boilers, and introducing types—as they undoubtedly had—English engineers did not intend to let them keep that lead if they could help it.

For war purposes, small swift ships, such as had been introduced, could not exist if it had not been for the locomotive boiler, and it was against this latter type that the water-tube boiler had to make good its claims. Mr. Yarrow was now building two vessels of the destroyer type. One would be fitted with a locomotive boiler, and one with water-tube boilers. That would be an excellent opportunity of testing the question, and he could not help saying that it was his opinion that the results, when they were tabulated, would not accord with Mr. Yarrow's opinion that economy was in favor of the locomotive boiler. No doubt Mr. Pratten's objection of the multitude of parts was a serious one, but they had to set against this the enormous gain in the matter of weight.

Mr. Milton, in replying to the discussion, said that it had been stated the Belleville boiler would not stand forcing, but if this type of boiler primed when driven hard, the same did not apply to other types to which he had referred, such as the Thornycroft or Yarrow boilers, which had been run very successfully at high rates of forcing.

THE NEW SPANISH CRUISER *INFANTA MARIA TERESA.*

The latest addition to the Spanish Navy—the cruiser *Infanta Maria Teresa*—which has been built and engined by La Sociedad Anonima de los Astilleros del Nervion (formerly Martinez-Rivas Palmer), at their splendidly equipped works at Bilbao, proceeded last week to Ferrol, in the north of Spain, to go on her steam trials. This is one of a fleet of ships for the construction of which the Spanish Government in 1889 voted an extraordinary credit of 10,000,000*l.* Through the influence of Mr. Martinez, one of the most enterprising capitalists in Spain, and that of his partner, Sir Charles Palmer, Bart., the experienced and vigorous head of the Jarrow firm, the building of three of the ships was intrusted to the Bilbao firm, one of the stipulations being that in every case preference must be given to Spanish material and industries—one of the primary objects being to foster the national industries, and more especially those of the province of Vizcaya.

In July, 1889, the contract between the Government and Don José Martinez de las Rivas for the construction of the hulls of the three cruisers was signed, and immediately afterwards efforts were begun to transform what was nothing but a marsh on the banks of the River Nervion into important shipbuilding, engineering and ordnance works. English managers and leading workmen were engaged by Sir Charles Palmer, and, after an enormous amount of labor, the various machine sheds, frame-bending sheds and furnaces, joiners' shops, &c., were erected; expensive machinery was brought from England, and the actual building of the ships begun. So strenuously was the work prosecuted, that in the short space of thirteen working months the first cruiser was launched with great *éclat* by the Queen Regent of Spain.

As stated in a former article,* when we gave a detailed description of the works, the original intention was to send out the principal parts of the machinery finished from Jarrow, where they were to be constructed at Messrs. Palmers'; but it was afterwards decided, upon the appointment of Mr. McKechnie as manager of the engine works, to build the engines in Spain, as he undertook the responsibility of the entire construction of the machinery at the Nevion Works. Thereupon the large and spacious engine and boiler shops, with iron and brass foundries, coppersmithy, bolt and rivet shop, &c., were begun, the most improved machinery being sent from this country. Everything progressed well till May 1, 1891, when the engine works were completely destroyed by fire. The work of reconstruction was tackled in a systematic manner, and with so much success that in three months the workshops were re-erected, and the construction of the cruisers' machinery proceeding as if nothing extraordinary had occurred. Many important parts of the engines were destroyed by the intense heat and by the water which was poured upon them during the progress of the fire.

In the beginning of 1892 the firm of Martinez-Rivas Palmer was transformed into a limited liability company,† with a capital of 1,200,000*l*, and the progress of work upon the ship and guns, as well as the reconstruction of the engines, went on satisfactorily until the end of April, 1892, when, through a disagreement between the firm and the Government, the works were temporarily closed. But the Government ultimately decided to take over the establishment with the intention of finishing the cruisers on their own account, and the English managers and workmen were retained upon their old terms. As official director over the concern, the Government appinted General Cervera, an experienced naval officer. Under his energetic efforts the work forged ahead, and his pleasant and gentlemanly manner gained him friends among Spaniards and Englishmen alike. He remained for about seven months in command of the Astilleros, when he was appointed Minister of Marine, being succeeded by General

*See "Engineering," vol. xlviii, page 504.

† *Ibid.*, vol. li, page 127.

Rocha, who has continued in charge up to the present. And now, after all the difficulties and troubles with which the undertaking has been beset since its beginning, the first of the three cruisers is completely finished and armed. The other two cruisers are in an advanced state, and may soon be completed. It is hoped that satisfactory arrangements will then be made for the continuance of the establishment.

Hitherto the Government has not been disposed to relinquish its control over the works until the cruisers were finished, and consequently discouraged the construction of merchant vessels. It is hoped now that as soon as terms have been settled with the company on the part of the Government either the company will be put in a position to carry on the works, or that they will be purchased by some of the capitalists who are credited with a desire to see the establishment as actively engaged as it might be. Certainly it is as well equipped as any British yard, and if encouragement is given, as is suggested by the Shipping Bounty Bill brought before the Legislature, the construction of these cruisers may mark an important epoch in the industrial history of Spain. The vessels built clearly prove what we have written as to the efficiency of the works, as will be appreciated from a short description, deferring fuller details until a later date, when we hope soon to fully illustrate the vessels and their machinery.

The *Infanta Maria Teresa* is built entirely of Siemens-Martin steel, is 340 feet long between perpendiculars, and 364 feet over all, with a breadth of 65 feet and a depth of 38 feet, displacing 7,000 tons on a mean draught of 21 feet 6 inches. She has the usual ram bow, and carries two masts, each having a military top and signaling yard. The masts and funnels have just enough rake to give her a very smart appearance. For 315 feet amidships she has an armor belt 5 feet 6 inches broad, backed by 6-inch teak. The plates, which were supplied by Messrs. Cammell and Co., are 12 inches thick, secured by 3½-inch bolts. She has the usual cellular double bottom, and has eleven transverse watertight bulkheads, the bunkers being arranged in the usual manner to afford the machinery as much protection as possible. She carries in all twelve boats, including a 60-foot

17-knot vedette boat, four large sailing pinnaces, a 30-foot gig, 28-foot whaleboat, two dinghies, a 25-foot canoe, and two 30-foot 8-knot steam launches, the machinery of the latter being constructed in the Astilleros. Forward she has a very powerful capstan, and a large warping winch aft, and is fitted with Muir and Caldwell's patent steam steering gear. The total bunker capacity is over 45,000 cubic feet, and 490 tons of fresh water are carried under the boilers. Her principal ground tackle consists of two 90-cwt. and two 30-cwt. ordinary anchors, two 80-cwt. stockless, and two kedge anchors of 14-cwt. and 8 cwt. respectively.

The pumping arrangements and ventilation of the ship have been well looked after, and throughout the whole ship a proper and complete system of voice-pipe arrangement has been instituted. Between the bridges, conning tower, steering gear, and engine rooms, as also between the engine and boiler rooms, &c., Messrs. Chadburns' patent telegraph gear has been fitted. Mr. James Clark, formerly of the Barrow Shipbuilding Company, who went to Bilbao at the commencement of the works, succeeded Mr. J. P. Wilson as manager of the shipbuilding department, and the short time in which the first cruiser was built speaks well for the management.

The ship has in all eight torpedo tubes, and the principal armament is as follows: Two 28-centimeter guns (one forward and one aft) mounted in barbette turrets,* ten 14-centimeter guns, two 7-centimeter guns, eight 57-millimeter Nordenfeldts, two 11-millimeter Nordenfeldts, and eight Hotchkiss. The forgings for these were brought from England, but they were turned and finished in the Astilleros Gun Factory, all the employés of which are Spaniards. This department is managed by Colonel Albairan, who has had considerable experience in the government gun factories, and who has satisfactorily finished the work intrusted to him, which excels by far similar work produced in the Spanish Royal Dockyards.

The propelling engines are of the vertical, triple-expansion, surface-condensing, direct-acting type, driving twin screws, and

* See "Engineering," Volume I, page 319.

are designed to develop collectively about 13,500 indicated horse power with forced draft, the contract speed for which is 20 knots. The dimensions of cylinders are: High pressure, 42 inches; intermediate pressure, 62 inches, and low pressure, 92 inches by 46 inches stroke. The cylinders are fitted throughout with Whitworth's fluid-compressed steel liners. In both engine and boiler rooms there is plenty of clear space. The cylinder-covers, pistons, and steam-chest doors are all of cast steel. The high-pressure cylinders are fitted with piston valves, and the intermediate pressure and low pressure with valves of the ordinary flat-faced double-ported type. The piston rods, which are 7¾ inches in diameter, are of Siemens-Martin steel, as are also all the forgings. The high-pressure rods are fitted with Beldam's patent packing, the packing for the intermediate pressure and low pressure having been supplied by the Combination Metallic Packing Company. The thrust blocks and collars are of cast steel, the latter being of the horseshoe shape and lined with "Magnolia" metal. The main surface condensers, which are 10 feet 8 inches long, are made entirely of brass, having a total surface of 14,600 square feet. Each condenser carries over 5,000 brass tubes 10 feet 8 inches by ⅝ inch in diameter. The crank shafts, which were supplied by Messrs. Cammell & Co., are of the ordinary three-throw type, being made of steel, the external diameter being 16⅛ inches. The reversing gear is of the ordinary all-round type, both hand and steam gear being provided. In each engine room there is a 100-gallon Kirkaldy's distiller, each with a circulating pump, as also an evaporator on Weir's system, with its 4-inch cylinder feed pump. There are four ash-hoisting engines, having two 4¼-inch cylinders by 5½-inch stroke, and efficient means have been provided for handling the ash buckets under forced draft. The engines for working the ammunition hoists are placed one forward and one aft, both working double hoists. The ammunition hoists themselves are provided with safety gear, to prevent the charges falling and causing an explosion on board, in case of the rope suspending them being shot away. The main steam pipes are 18 inches in diameter,

and are all of copper, the sheets having been brazed and wrought up in the coppersmithy.

Forward of the mainmast a boat-hoisting engine has been fitted, having 9-inch cylinders, and capable of lifting 18 tons, the mast being provided with a suitable boom for raising and lowering the heaviest boats. Air-compressing machinery, supplied by Schwartzkopff, for charging the torpedo tubes and torpedoes, has also been fitted for working up to 1,500 pounds pressure. The exhaust steam from the auxiliary machinery is carried into two auxiliary condensers 8 feet long—one in each engine room—each condenser being provided with its own air and circulating pumps, which are worked by entirely independent engines. These condensers, like the main, are made entirely of brass, and each contains about 700 tubes.

In all there are over fifty separate and auxiliary engines, the whole of which, excepting the windlass, steering gear, distillers, and vedette boat machinery, have been constructed in the Astilleros. In a situation convenient to the engine room an engineers' workshop has been erected, and fully provided with all the requisite machines, tools and grindstones. The two propellers are three-bladed, and cast of Stone's patent No. 3 bronze, the bosses and tail pieces being of gun metal, and the blades fixed by bolts in the usual manner. The propellers have a diameter of 16 feet 5 inches, and 20 feet 6 inches pitch, the expanded surface being 73 square feet. For each engine there are four lengths of straight shafting, which was supplied rough turned and finished in the Astilleros. The diameter of the intermediate shafting is 15¼ inches, that of propeller shafting being 15¾ inches.

Steam is supplied by four double-ended boilers 16 feet 3 inches in diameter, and two single-ended boilers 15 feet 3 inches in diameter by 10 feet 6 inches long, and working at a pressure of 150 pounds per square inch, the test pressure being 250. Following out the usual plan to provide greater safety, the boilers are placed in two separate compartments, the bunkers being run along each side in the usual way. There are two funnels, 9 feet in diameter, the height from dead-plate to top of funnel being 69

feet. There are in all 40 Purves' patent boiler flues, 6 feet 6 inches long and having a mean diameter of 3 feet 3 inches. The double-ended boiler tubes are 6 feet 3 inches by 2½ inches, the single-ended boiler tubes being 6 feet 9 inches by 2½ inches. The grate surface is 845 square feet; tube surface, 22,270 square feet; heating surface, 25,920 square feet. For supplying steam to the electric-light and steering-gear engines there are two auxiliary boilers on the protective deck forward, each 8 feet 10 inches long by 7 feet 9 inches in diameter, with a 3¼-inch Worthington system pump provided. The usual stokehold arrangements for running under forced draft have been fitted, there being nine fans, having a diameter of 5 feet 6 inches. The designing and construction of the engines, boilers, and auxiliary machinery, as well as the construction and equipment of the engine works, have been carried out by Mr. James McKechnie, who has been assisted by Mr. James Brown, formerly of the Clydebank engineering staff.

The *Infanta Maria Teresa* went out from Ferrol on her official natural-draft trials on September 18th. The draft of the vessel was 21-feet 6-inches, the displacement being 6,890 tons. The vessel steamed for eight hours at sea, with a heavy swell running in from the Atlantic, and the results were extremely satisfactory, far exceeding expectations, while everything worked splendidly. The fans were running merely for efficiently ventilating the stokehold, and the pressure recorded by water gauge was $\frac{3}{16}$ inch. Of course there was no difficulty with tubes. A plentiful supply of steam was maintained at a mean pressure of 145 pounds per square inch. The mean power of the half-hourly records of the engines was for the starboard set 4,686 indicated horse power at 105 revolutions, and for the port engine 4,872 indicated horse power at 106 revolutions, a total of 9,558 indicated horse power. The vacuum was 27½ inches. The method taken to arrive at the speed of the ship was as follows: The vessel ran over the measured mile four times before and four times after the run at sea, during which runs the Naval Commissioner from Madrid ascertained the number of revolutions corresponding to one nautical mile. The

average number of the eight runs on the measured mile was adopted as the means of ascertaining the speed of the vessel in nautical miles during the trial at sea. The speed worked out at 18.48 knots. The highest speed record was at the rate of 18.8 knots. The guarantee was 18 knots, so that the result is most satisfactory. It may be added that if the mean speed attained by the vessel at the trials had been less than 18 knots, without falling below 17½ knots, the vessel would have been accepted only on payment by the builders of 80,000 pesetas for each complete tenth part of a mile per hour that had not been attained.

The official forced-draft trials took place on Saturday, October 14th, when the somewhat onerous requirements of the contract were fulfilled. A full supply of steam was to be maintained at 145 pounds per square inch with an air pressure of 1.5 inches, and the speed of the vessel was to be 20 knots, the mean draught being 21 feet 6 inches, and the displacement 6,890 tons.

To determine the speed of the vessel under these conditions, the following measures were taken: A measured distance, 1.412 knots, was run over four times, twice in one and twice in the opposite direction, and the mean number of revolutions corresponding to a nautical mile ascertained. After that the sea run for nearly two hours was made, still under forced draft. At the termination of the sea trial the runs over the measured distance were repeated. The average of the number of revolutions ascertained during the runs over the measured distance served as the divisor to ascertain the speed in nautical miles attained by the ship during the two hours' run at sea. The penalty for each complete tenth of a mile per hour under the 20 knots was 26,666 pesetas. The speed, however, it was found after the trial, worked out at 20.25 knots for the 4½ hours during which the vessel was out on Saturday. The weather was fine, but there was a heavy Atlantic swell, and the currents at the entrance to the harbor of Ferrol, where the measured distance is situated, tended to reduce speed, owing to the difficulty of maintaining a straight course. The following are the results as cabled to us; and with them we give the results of the natural-draft trial already described in a previous issue.

	Natural draft.	*Forced draft.*
Mean speed (knots),	18.5	20.25
Indicated horse power, starboard,	4,686	6,857
Indicated horse power, port,	4,872	6,901
Indicated horse power, total,	9,558	13,758
Revolutions, starboard,	105	118
Revolutions, port,	106	118
Vacuum, starboard,	27½	27½
Vacuum, port,	27½	28
Steam pressure (pounds),	145	145
Air pressure (inches),	$\frac{3}{16}$	1

The indicated horse power works out to 16.28 per square foot of grate area, while each indicated horse power corresponds to 1.883 square feet of heating surface.

The Spanish cruiser *Infanta Maria Teresa*, described in a recent issue (page 338 *ante*), has completed her series of trials with a long test as to coal consumption. The vessel left Ferrol at 3 o'clock on October 18, the weather being fine, with a slight swell from the Atlantic. The vessel ran six times over the measured distance of 1.412 nautical miles, and afterwards proceeded on a twelve hours' run to sea, finishing next morning at 6 o'clock. Four double-ended boilers were employed to supply the steam required for the main engines, and one single-ended boiler for the steam for steering-gear engine, electric-light engine, auxiliary circulating pumps, and bilge pumps. The coal consumption per indicated horse power per hour allowed by contract was 680 grammes = 1½ pounds. Two sets of diagrams were taken from each set of engines every half hour, and the mean indicated horse power developed during the twelve hours was 1,238. The coal consumed in the main boilers during the twelve hours was 62 measures, previously weighed, each containing 165 kilogrammes = 10,230 kilogrammes, or at the rate of 852.5 kilogrammes per hour. It was computed that the two main circulating pumps and the two main feed pumps would consume double the fuel per indicated horse power of the main engines, and on this assumption the consumption of the main engines worked out at

597 grammes per indicated horse power per hour. But even if the consumption of the pumps be included, the consumption is well under contract. The results of the working of the single-ended boiler for eight hours showed a consumption of 1,980 kilogrammes, or 247.5 kilogrammes per hour. The power was as follows: Two auxiliary circulating pumps, 19; two fire and bilge pumps, 40; steering-gear engine, 75; electric-light engine, 55; auxiliary feed pump, 13; total, 202. The consumption was, therefore, 1.22 kilogrammes per indicated horse power per hour for these auxiliary machines.

On Thursday, October 19, the vessel went through turning trials at 10 and 16 knots speed, with satisfactory results. She subsequently proceeded on single-screw trial. This latter was run with the port engine, and the speed was 12½ knots, with the engine making 85 revolutions. It may be here noted that the natural-draft speed, with both engines making 106 revolutions, was 18½ knots, while with forced draft the speed was 20¼ knots, with the engines making 118 revolutions. There was then a trial to find the minimum speed at which the engines could be run. This proved to be 13 revolutions, which was kept up for about 10 minutes. This is equal to 2.62 knots, without allowing for slip. The trials from first to last were exceptionally severe, and equally satisfactory, and the commissioners from Madrid expressed themselves as being highly delighted with the exhaustive tests to which the machinery had been subjected, and expressed the opinion that no navy in the world had a finer ship, or machinery which had been put to such severe tests, and with such excellent results.—"Engineering".

APPARATUS FOR ASCERTAINING THE EFFICIENCY OF SCREW PROPELLERS.

The direct benefits that have resulted from experimental investigations at the Admiralty Experimental Works, Gosport, and which include, among other things, a general advancement of speed in our war ships, have imbued other nations with the desire to be able to ascertain the probable speed of particular forms of ships from experiments with small-scale models. Some three years ago the Italian naval authorities erected an experimental tank at Spezzia, and the Russian Admiralty are at present busily engaged with the construction and equipment of similar works at St. Petersburg; while the progressive spirit of American Naval designers has already turned itself in this direction, and there is every possibility of a tank being established in the United States in the near future. Both the Russian and Italian establishments are similar to the works at Haslar, the arrangement of which, and the design of many of the appliances forming its equipment, are due to the genius of Mr. R. E. Froude, son of the late Dr. William Froude, the originator of the experimental system of investigation with ships' models.

The special apparatus for determining the relation of speed to power of ships from their models, and the "screw truck," or machine for recording the efficiency of propellers, to be used in the new Russian tank, were some time ago completed and despatched to St. Petersburg by Messrs. Kelso & Co., Commerce street, Glasgow, who also supplied the apparatus for the tank at Spezzia to the order of the Italian Government. In design, the new Russian equipment is similar to that in use at Haslar, and the outfit proper comprises the dynamometer carriage, the screw propeller carriage, and the current meter, the latter being specially adapted for recording the currents, or motion of the water in the tank, if there be any.

Three years ago (see *Industries*, 8th February, 1889) we placed before our readers a detailed description of the dynamometric apparatus supplied to the Italian tank, which is, practically speaking, identical with that constructed for the Russian Government. We are now enabled to describe the screw propeller truck, the primary use of which is to ascertain the most suitable propeller for maximum efficiency, when used in conjunction with a particular form of vessel. The propeller on which experiments are to be made is mounted on a shaft carried by knife-edged brackets and supported by a frame attached to a delicate parallel motion. A vertical spindle at the after end of the frame drives the screw shaft by means of miter wheels, the spindle itself being driven by a series of belts and polygrooved pulleys from the axles of the main truck. This main truck, which supports both the dynamometer and screw carriages, spans the entire breadth of the tank, and runs on a railway extending the whole length of the tank at a height of about 18 inches above the normal water level. Any desirable linear speed of advance of the screw through the water may be given by proportionately adjusting the rotary motion of the polygrooved wheels. From Figs. 1 and 3 it will be seen that the main framework is capable of being raised or lowered by means of screws, a feature which admits of any desired immersion being given to the screw under experiment. Fig. 2 is a diagrammatic illustration of the apparatus showing the relative position of the screw at the stern of the model ship. A is the parallel-motion swinging frame, B B B the balance weights, C the revolving cylinder, S S helical springs for measuring the thrust and turning moment of the screw, T thrust pen, T^1 turning-moment pen, R revolution pen, and P P polygrooved pulleys. As will be seen, the parallel-motion framework is suspended by delicate watch springs from the body of the carriage. It constrains the frame carrying the model screw to move simply in a fore-and-aft direction. The whole is so delicately balanced that the slightest force exerted by the screw as a thrust is recorded on a revolving cylinder through the extension of a spiral spring attached to a bell crank lever carrying a pen rod, the bell crank lever being connected by a link to

the parallel-motion framework (see Fig. 2). Another band passes over a system of delicately suspended levers and pulleys, by which the differences in tension on the driving and slack sides of the belt are automatically recorded on the same cylinder, and in a similar manner to the thrust. This difference in tension is a measure of the turning moment applied to the mechanism.

It may here be mentioned that great care has been bestowed, alike in design and workmanship, with a view to minimizing the effect of friction, especially in regard to the methods of suspending the delicate levers and mounting the various pulleys, many of the latter being supported on friction wheels. In addition to the thrust and turning moment, the revolutions of the screw are also electrically recorded on the cylinder, and, as any given speed over the water can be assigned to the propeller carriage, curves of thrust and turning moment may be obtained in terms of revolutions of screw at that speed. From these curves the efficiency at any required number of revolutions may readily be determined.

The screw truck may be used separately or in conjunction with the dynamometric apparatus, and the effect ascertained of the model's presence on the efficiency of the screw, or the screw's influence in augmenting the resistance of the model of the ship under consideration. The behavior of either single or twin-screws may be obtained in relation to the model, and the best position of the propeller in regard to the hull may be decided upon, to realize the maximum efficiency of the hull and propeller combined. In short, with this apparatus the performance of any given screw may be determined, and the most suitable relationship of diameter to pitch and blade area selected, to secure the best results when used in conjunction with any particular form of hull, and this at moderate cost before the ship is actually constructed.—"Industries."

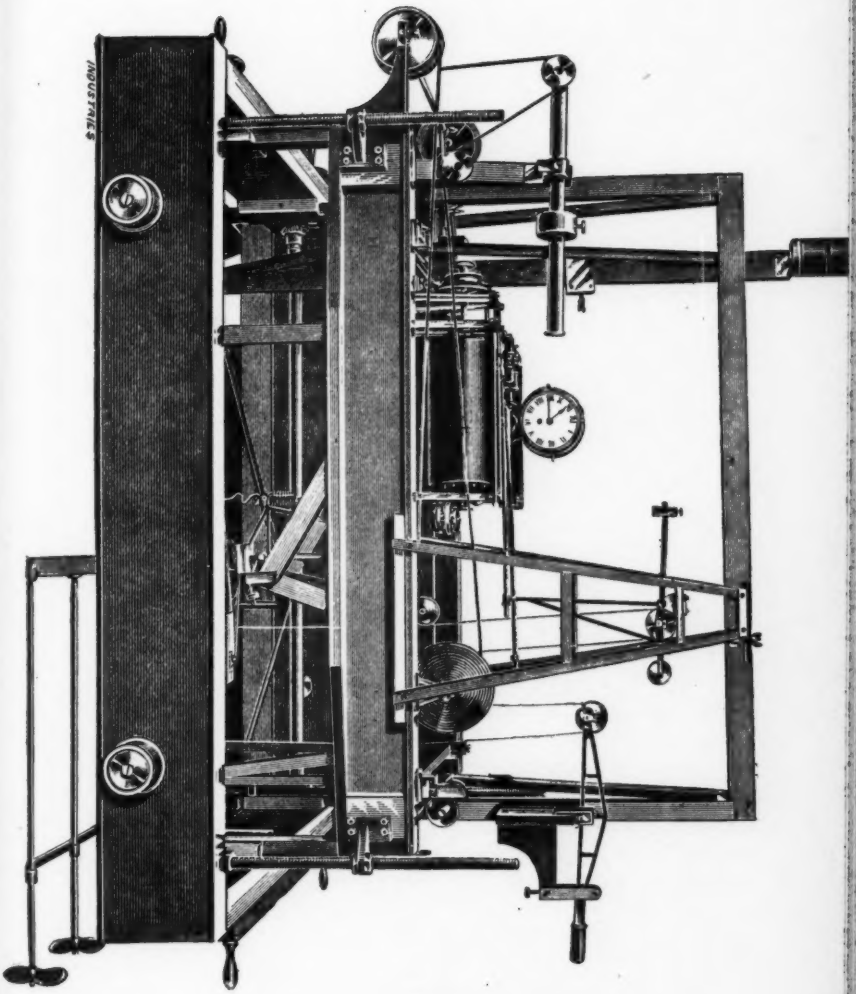


Fig. 1.

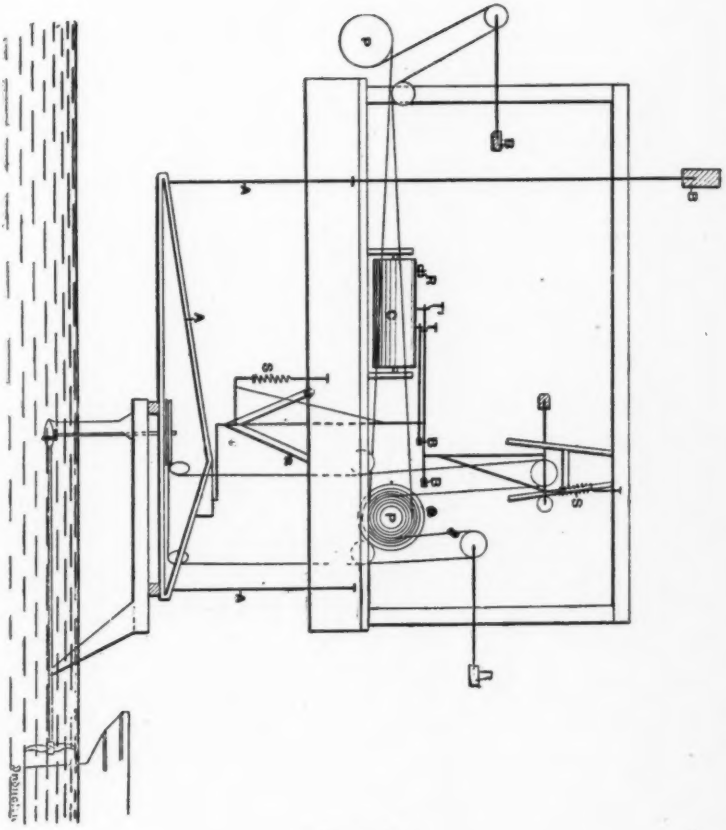


Fig. 2.

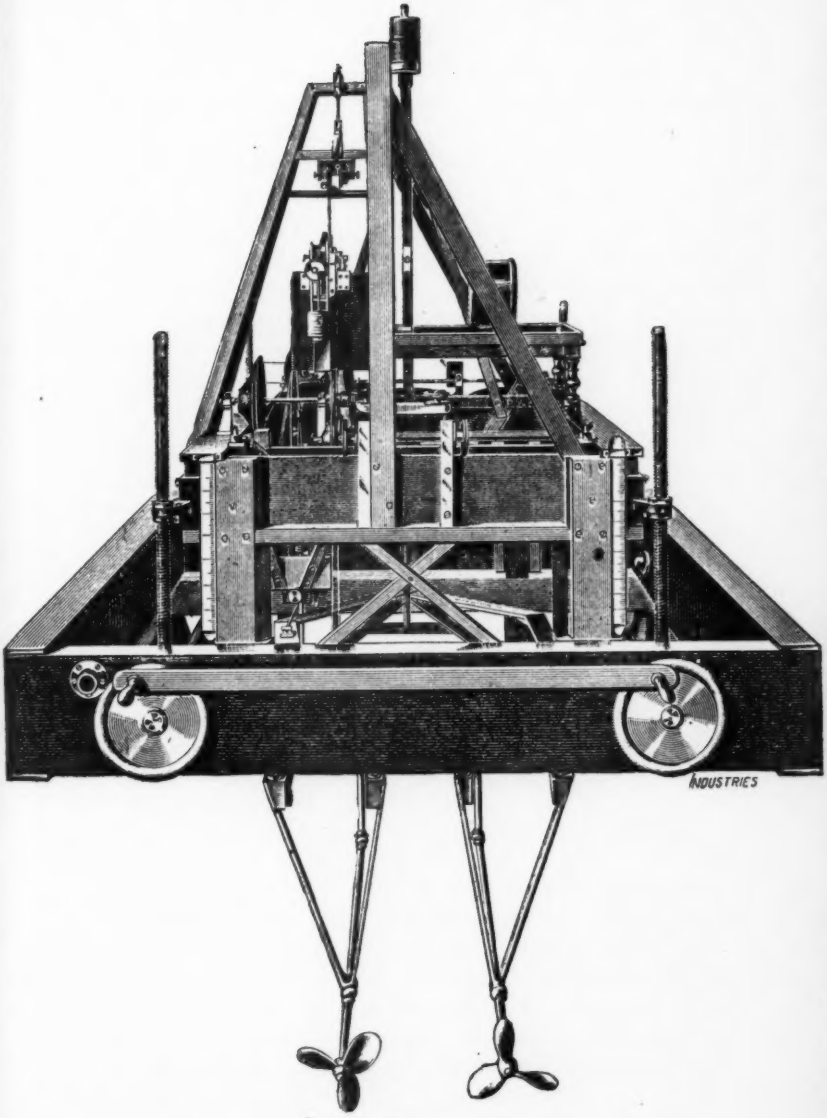


Fig. 3.

NOTES ON PERFORMANCE OF S.S. *CITY OF ALPENA.*

By E. L. McAllaster, Esq., Associate.

The *City of Alpena* and *City of Mackinac* are duplicate side-wheel steamers, built this past season for the Lake Huron division of the Detroit and Cleveland Steam Navigation Company by the Detroit Dry Dock Company, from designs of Mr. F. E. Kirby. They are 275 feet length on deck, 15 feet molded depth, and 68 feet in breadth, molded, over guards. The hulls are of steel, made to the following specification:

"REQUIREMENTS FOR SOFT SHIP STEEL.

"All to be of open-hearth manufacture.

"Tensile strength, 52,000 to 60,000 pounds.

"Elastic limit, at least ½ ultimate.

"Elongation, 25 per cent. in 8 inches.

"Reduction, at least 45 per cent.

"Fracture, silky.

"Phosphorus not to exceed .08 per cent.

"From a plate of each ingot of steel used a crop end shall be tested by punching a ¾-inch hole—the center of the hole being 1⅛ inches from the sheared edge—without fracture.

"Material to be tested for tensile and bending tests by melts from strips cut from material as rolled for orders.

"All material to be stamped by melt number for identification in inspecting.

"Actual weight of each piece of material to be within 2½ per cent. of theoretical weight. No lighter weight will be accepted, but overweight may be accepted if billed at theoretical weight.

"All steel to be subject to the approval or rejection of the Superintending Engineer, and memoranda of each shipment to be furnished to inspectors, who *shall* approve each invoice as being satisfactory and in accordance with the specifications before shipment.

"Makers to furnish inspector's analysis of each melt of steel, and to furnish all necessary test specimens and to give all necessary assistance for testing material."

The main saloon is mahogany, and the dining saloon in the after hold is finished in oak. They are heated by steam and lighted by electricity, a search light being added to each one. The dining saloon is ventilated by a steam fan. Each boat has a complete annunciator system, to which all staterooms and officers' rooms are connected. Bath rooms, smoking room and barber shop are added for the benefit of cabin passengers.

At two points on the route the vessels run a considerable distance up narrow rivers, and have to back out or be towed out. For convenience in handling, the engines are fitted with steam handling gear, and a rudder is fitted to the bow of the boat. The steering in backing out of these places is done by a hand wheel in the pilot house in the usual way, the steam gear for ordinary steering being locked in mid position, and *vice versa.* They readily back out of these places at a speed of 20 revolutions per minute.

They carry both freight and passengers between Toledo, O., Mackinac Island and intermediate points. Each boat makes two round trips, or about 1,700 miles per week. They are allowed on regular trips 395 cabin and 105 deck passengers.

The trip on which these notes were taken was only the latter part of a much longer journey taken by the writer, and there were no departures from the ordinary working during the trip or facilities for making a test of the vessel's capabilities, hence the incompleteness of the data. The average steam pressure was nearly 95 pounds.

The following are some of the hull data:

Length, L.W.L., feet	266
Breadth moulded, feet and inches	38–6
Immersed midship area, moulded, at 9 feet $2\frac{3}{4}$ inches moulded draught, square feet	327.4
Cylindrical co-efficient $= \frac{1.712 \times 32}{266 \times 327.4} =$	0.629
Block co-efficient $= \frac{1.712 \times 32}{266 \times 3.85 \times 9.28} =$	0.576

The engines were built by the W. and A. Fletcher Co. of New York, and are compound, beam, condensing, with feathering wheels.

H.P. cylinder, diameter and stroke, inches	42 × 88
L.P. cylinder, diameter and stroke, inches	66 × 132
Wheels, diameter, outside buckets, feet and inches	25-7
Wheels, diameter, centers of suspension, feet and inches	22-6
No. buckets, each wheel	10
Face of buckets × breadth, feet and inches	10 × 3-6
No. buckets immersed on this run, both wheels	4
Height of center of shaft above water, feet and inches	8-8½
Immersion of lower edge of buckets, feet and inches	4-1
Radius of rolling circle, for mean of run, feet and inches	8-10¾
Immersion of rolling circle, feet and inches	0-2¼

Boilers, double-ended, Howden system of forced draft.

Number	2
Mean diameter, feet	12
Length over heads, feet and inches	19-7⅝
Working pressure, pounds per square inch	120
Total grate surface, square feet	160
Total heating surface, square feet	6,566
Blower	1
Diameter, inches	66
Area of air main, square inches	1,296
Engine, double, horizontal, direct, inches	6 × 6

PERFORMANCE, STEAMER *CITY OF ALPENA*, AUGUST 12 AND 13, 1893.

From—	To—	Miles—5,280 feet.	Time.	Miles per hour.	Total revolutions.	Revolutions per minute.	Revolutions per mile.	Slip, per cent., on diameter, 22⅝ feet.	Mean draught.	Displacement (net tons).
			h. m. s.						*Ft. in.*	
Mackinac Island..	Cheboygan...	16	0.59 50	16.045	1,562	26.11	97.625	23.48	9-2	1,685
Cheboygan	Alpena	99	5.47.10	17.11	9,297	26.77	93.909	20.45	9-2.4	1,693
Alpena	Oscoda	52	2.57.45	17.55	4,774	26.85	91.807	18.64	9-3.9	1,720
Oscoda	Sand Beach .	55½	3.21.00	16.567	5,338	26.55	96.180	22.33	9-4.3	1,729
Sand Beach.....	Lexington.....	43	2.30.25	17.152	4,035	26.82	93.837	20.39	9-4.4	1,730
Lexington	Fort Gratiot Light.	20	1.12.00	16.130	1,972	27.39	98.60	24.25	9-4.2	1,726
Mackinac Island..	Fort Gratiot Light.	285½	16.48.10	16.991	26,978	26.76	94.494	20.947	9-3.4	1,712

I.H.P. at 8 feet 11 inches mean draught and 28.5 revolutions was 2,398. For this run it is assumed to be—

$$\frac{2{,}398 \times (26.76)^3}{(28.5)^3} = 1{,}985.$$

$$C = \frac{S^3 \times D^{\frac{2}{3}}}{\text{I.H.P.}} = \frac{(16.991)^3 \times (1{,}712)^{\frac{2}{3}}}{1{,}985} = 353.6.$$

C for gross tons and knots = 214.7.

Indicated thrust, pounds, $= \frac{1{,}985 \times 33{,}000}{26.76 \times 70.686} = 34{,}630.$

Indicated thrust, pounds, per square foot of immersed bucket

$$= \frac{34{,}630}{4 \times 10 \times 3.5} = 247.35.$$

ENGINE VIBRATION.

The question of steamship vibration is now attracting a good deal of attention in a very unpleasant manner. To obtain the high speeds demanded by travelers in the present rushing age, engineers and naval architects have both been compelled to lighten their structures. In the ship's hull this has been done by the introduction of steel in place of iron, the scantling has been reduced, and the consequence has been a lighter and more elastic structure. The engineer on his part has increased the number of revolutions, and though reciprocating parts in the engines have been lightened, the jar caused by bringing to rest and starting again the moving parts is a very serious matter. The apparently eccentric manner in which steamers would vibrate or be comparatively still at different times, was, for a long time, a puzzle to engineers, but the laws which govern the question are now fairly well understood in fundamental principles. It was in torpedo boats—those pioneers of so much recent practice in marine engineering—that the remarkable effects of vibration were first studied, and it is to the torpedo-boat builders that the solution of the question is mainly due. The propeller itself was long credited with the odium of vibration, but investigations of a practical and theoretical nature have shown that a well-balanced propeller adds little, if anything, to this evil; the chief cause of which is the reciprocatory movement of the engines, and it is when the reciprocations synchronise with the natural period of vibration of the hull that the vibration reaches its maximum effect.

All this, our readers will remember, was most excellently put forward at the spring meeting last year of the Institution of Naval Architects, when Mr. Yarrow read his well-known paper on the subject.*

* See "Engineering," vol. liii, page 434.

The remarkable effect in damping vibration produced by the addition of what Mr. Yarrow called "bobweights," which moved in a vertical direction, so as to balance the vertical movement of the reciprocating parts of the engine, will be remembered. Mr. Yarrow then illustrated his reasoning by means of working models shown at the meeting, but he has since put some of the principles enunciated into actual practice, and we have lately had an opportunity of seeing an engine of 1,600 horse power fitted with balance weights with the most happy results. To perfectly balance an engine, it is necessary to fit the vertically-moving bobweights, but for practical purposes on shipboard it may be as well to dispense with this and use only rotating weights for balancing purposes. By the use of rotating weights, engines may be balanced vertically, although vibrations in a horizontal direction will still be present, the latter, however, owing to the shape of a vessel's hull, are not important.

On the annexed illustration, in Fig. 1, is shown diagrammatically the arrangement of engine used for the experiments we are about to describe. The engine was fitted up in the machine shop at Messrs. Yarrow's works, being supported in the middle by a short block of wood. At each end were india-rubber discs as shown. It will be seen that the engine was, therefore, free to oscillate endwise, in seesaw fashion, so far as the elasticity of the discs would allow. The engine is, as stated, of 1,600 horsepower, and is of the three-cylinder, tri-compound type, with three cranks. In the paper before referred to, Mr. Yarrow makes the following statements with regard to this type of engine: "Triple-expansion engines with three cranks, although partially balanced when at rest, are very far from being balanced when at work, owing to the distance between the various reciprocating parts, which consequently set up a rocking motion, which is the principal one to be overcome, and in such engines we have to deal with this rocking motion in addition to the vertical motion of the center of gravity, this vertical motion being due to the difference in weight of the working parts of the three engines. In a single-cylinder engine the vibration is practically up and down. In a double-cylinder engine, with cranks at right angles,

Fig. 1.

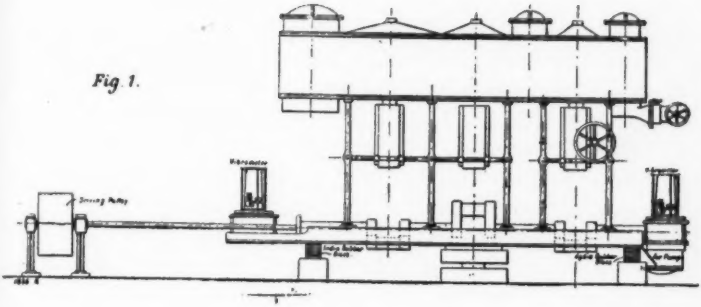
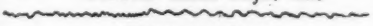
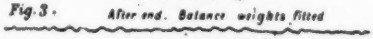


Fig. 2. Forward end. Balance weights fitted.



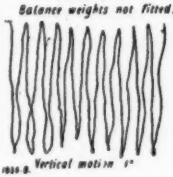
Vertical motion 3/8"

Fig. 3. After end. Balance weights fitted



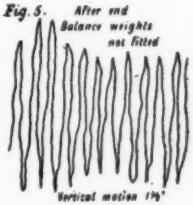
Vertical motion 3/16"

Fig. 4. Forward end Balance weights not fitted.



1838 B. Vertical motion 1"

Fig. 5. After end Balance weights not fitted

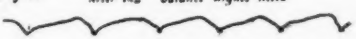


Vertical motion 1⅝"

Fig. 6 Forward end. Balance weights fitted.

Vertical motion ½"

Fig. 7. After end Balance wights fitted



Vertical motion 1/8"

Fig. 8. Forward end Balance weights not fitted

Vertical motion 3¼"

1838 C

Fig. 9. After end Balance weights not fitted

Vertical motion 3⅛"

it is a more pronounced galloping motion, *i. e.*, a motion of a complex kind, being a compound of vertical motions of their center of gravity and a rocking motion.

"Some years ago we thought the vibration in triple-expansion engines was due to the difference in weight of the pistons, and with a view to balance them, and, as we supposed, avoid vibration, we made each piston of the same weight in a first-class torpedo boat. Thus we prevented any vertical movements of the center of gravity of the engines; yet we found no improvement. This clearly indicates that the rocking vibrations are of more importance than the vertical vibrations in triple-expansion engines." We quote these passages from Mr. Yarrow's paper in order to assist our readers' memories; but to fully grasp the bearing of the present experiments, all the details of the paper should be had in recollection.

As shown by the illustration, the engine was driven by a pulley connected to its crank shaft by means of a length of shafting, having considerable play, in order to allow for the vibrations of the engine. The trials were divided into two parts: those made without balance weights, and those with balance weights fitted. These weights were attached to the crank webs in the usual manner, the effect of all the moving parts being carefully calculated, and the balance weights so proportioned as to counteract the movement, so far as vertical motion was concerned. The principle adopted was, in fact, the same as that usually followed in locomotive practice; but whereas in a locomotive it is the horizontal disturbing forces, due to the motion of the reciprocating parts, which are balanced, and the vertical lifts unbalanced, in Mr. Yarrow's engines the reverse was the case.

We reproduce diagrams taken. In the first four diagrams, Figs. 2 to 5, the revolutions were 72 per minute, and the records were obtained by means of vibrometers fixed on the forward and after ends of the engine base, as shown in the illustration. In Figs. 2 and 3 the balance weights were fitted, and it will be seen that the movement was very small, in one case the deviations from the straight line amounting to $\frac{1}{16}$ inch, whilst in the second case they were $\frac{3}{64}$ inch. Figs. 4 and 5 show the effect of remov-

ing the balance weights. On the forward end the pencil of the vibrometer had moved, relatively to the paper, through a vertical distance of 1 inch, whilst on the after end the movement was about $\frac{1}{8}$ inch more as a maximum. It will be remembered that a description of the vibrometer was given in Mr. Yarrow's paper before referred to. The last four diagrams were taken direct from the bedplate at the forward and after ends. These records were obtained by fixing a pencil on to the bedplate itself, a suitable adjustment by means of a spring having been provided to keep the pencil in contact with the paper. The papers were, of course, supported by the floor of the shop. The papers were continuous, and were wound on a drum so as to obtain the necessary horizontal motion. This last mode of obtaining the diagrams was selected because the vertical range of the vibrometer was not sufficient to record the oscillations of the higher speed of 78 revolutions when the balance weights were not fitted. The records speak for themselves. It will be seen that with the balance weights the vertical motion was but $\frac{1}{8}$ inch, whilst without the balance weights the range was from $3\frac{1}{2}$ inches to $3\frac{7}{8}$ inches. The value of balance weights is well shown by this illustration, but they must be balance weights actually, not merely in name. For this reason the calculations governing their position must be carefully made and all factors considered. The thanks of the marine engineers are certainly due to Mr. Yarrow for his researches in this important matter of vibrations, and more especially for the liberal manner in which he has placed the results of his labors so freely at their service.—" Engineering."

The following letter to " Engineering " from M. Normand, the well-known torpedo-boat builder, will prove of interest in connection with the foregoing article :

" To the Editor of Engineering :

" Sir: In your number of September 11, 1891, six months before the reading of Mr. Yarrow's important paper on the balancing of engines, you described an arrangement which I intended to use in order to destroy vibrations on board overpowered light vessels.

"It may interest your readers to know that I have just tested the arrangement for the first time on the double-screw torpedo-boat the *Chevalier*, of 115 tons displacement, officially tried at Cherbourg last week.

"At all speeds, up to 27.22 knots (mean of one hour, and perhaps the highest ever recorded) the vibrations were found to be unusually small. As the valves and pumps are not balanced, some slight motion (a great part of which is due to the screws) still remains, but it is quite unimportant, and the writing on the notebooks shows no appreciable difference from what it would have been on shore.

"It may be worth recalling the principle of the improvement. The engines are triple-expansion, with three cranks at 120 degrees.

"The weights of the three pistons, piston-rods, and connecting-rods are identical, and it is remarkable that in this case the sum of the three forces of inertia is always *nil, whatever be the length of the connecting-rod.*

"Let F be the force of inertia of the moving parts of one cylinder in kilogrammes.

"P the weight of these moving parts (piston, piston-rod, and about one-half of the connecting-rod) in kilogrammes.

"G the stroke in meters.

"m the ratio of the length of the connecting-rod to that of the crank.

"n the number of revolutions per second.

"ψ the angle of the crank with the axis of the cylinder.

"Then,

$$F = -2.01\ PGn^2 \left(\cos \psi + \frac{1}{m} \cos 2\psi \right).$$

Now, if the angular distances of the three cranks are 120 degrees, the force of inertia F^1 for the second cylinder will be:

$$F' = -2.01\ PGn^2 \left\{ \cos (\psi + 120°) + \frac{1}{m} \cos (2\psi + 240°) \right\}$$

and the force F'' for the third cylinder:

$$F'' = -2.01\ PGn^2 \left\{ \cos (\psi + 240°) + \frac{1}{m} \cos (2\psi + 480°) \right\}$$

It is easy to prove that

$$\text{Cos } \psi + \cos (\psi + 120°) + \cos (\psi + 240°) = 0,$$

and

$$\text{Cos } 2\psi + \cos (2\psi + 240°) + \cos (2\psi + 480°) = 0.$$

So that the sum of the three forces of inertia,

$$F + F' + F'' = -2.01\ PGn^2 \left(0 + \frac{1}{m}\,0\right) = 0.$$

"The same reasoning applies to four cranks at 90 degrees.

"But, as the three forces are not situated on the same axis, there remains a vertical couple proportional to the distance between the fore-and-aft cylinders, and if this couple were not destroyed, the engines would take an oscillating or rocking motion.

"Now, a couple may be equilibrated by any other equal couple situated in the same plane, provided that the figure of the whole system is invariable.

"In this particular case the principle is applied in the following manner:

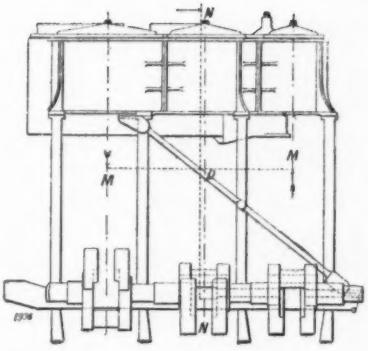
"*a.* The engines are rendered invariable by strong diagonal braces, D, connecting the cylinders with the bed plates.

"*b.* The vertical couple M M, which would give to the hull a vertical undulatory motion, is replaced by a horizontal one, N N, the strains of which are destroyed by horizontal stays riveted to the deck, and by the fastenings of the bed plates with the bottom of the ship.

"It is evident that horizontal efforts applied lengthways to the deck and bottom plating produce less motion and exert less strains on the material than would vertical efforts applied perpendicularly.

"The figure shows also the great advantage of giving to the engines the shortest possible length, since the couple to be destroyed is reduced proportionately.

"It is most important to state that, without the very strong diagonally longitudinal bracing of the engines, and the horizontal stays at the top, the equalization of the weights of the moving parts would increase the rocking motion, since the inertia couple would be augmented, especially with very long engines. Be-


N
M
M
D
N

sides, the working of the engines would be very defective, since the axis of the cylinders would not remain always perpendicular to the shaft.

"No doubt the horizontal and longitudinal stays at top of engines are very often used; so are slight diagonal braces; but in order to get a good result the whole system must be applied without any omission.

"If we compare this mode of destroying vibration with that proposed by Mr. Yarrow, we see that it offers the following advantages:

"1. It requires no extra moving parts.

"2. The balancing strains are applied to the cylinders, duly strengthened locally for that purpose, and not transversely to the crank shaft, which is the part of the engines most liable to breaking.

"3. It does not increase the length of the engines.

"Although our arrangement is specially designed for very light vessels, such as torpedo boats or catchers, where the strength of the engines is greater than that of the hull, it may be applied also to large vessels, but not in the same manner, in order to avoid damage to the engines.

"In the hope that you may find place for this letter, on account of the increasing interest which attaches to anything relating to the vibration of vessels,

"I remain, Sir, yours sincerely,

"J. A. NORMAND, M. I. N. A.

"Havre, October 18, 1893."

TWO MODERN METHODS OF INTRODUCING FEED WATER INTO MARINE BOILERS.

[From the "Iron Age," New York.]

That the marine boiler should require a greater degree of care in its general management than the land or stationary boiler may not, at first glance, appear to be reasonable, nor is it contended that such precautionary measures as may be considered best for the former are not also well adapted to the latter; but it is a well-known fact that the land boiler, by reason of its greater accessibility, more advantageous situation, ampler heating surfaces and freedom from over forcing, is in a great measure relieved from those excessive strains and destructive influences which are constantly affecting the boilers of a steamship. Besides this, on shore it is not difficult to provide large and efficient outside feed-water heaters, all needed room being available, while in the hold of a steamer this is less readily done. Of necessity the marine boiler is more cramped in its quarters or allotted space, and in its proportion of heating surface, so that in order to preserve it for a rational "life time" there can be no relaxation of watchfulness nor any preservative method neglected. Since the adoption of forced draft, whereby such an increase of power has been obtained, the temperature in furnaces and tubes has risen greatly, and many casualties have occurred and many boilers been practically destroyed or rendered unfit for their designed purpose just by attempting to produce this increased power without any additional precautions being taken in management against the injurious effects of allowing cold air to rush in open furnace doors or feed water being badly directed or of too low a temperature.

The old conditions of having comparatively cool water in the bottoms of the boilers, while that of the upper portion is boiling,

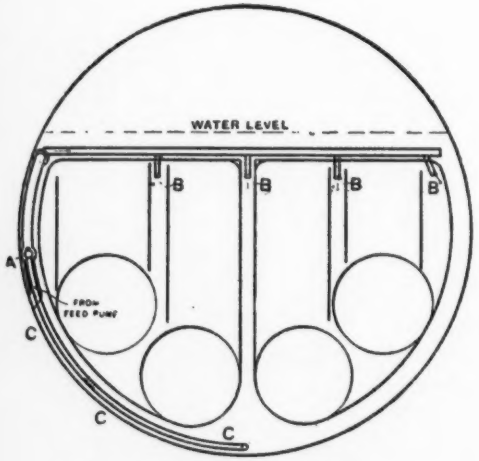


Fig 1 —Section of Marine Boiler.

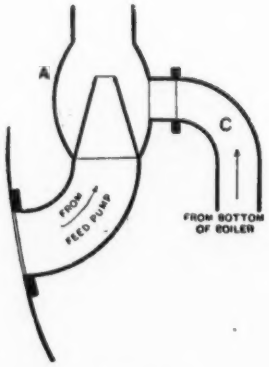


Fig. 3.—Injector.

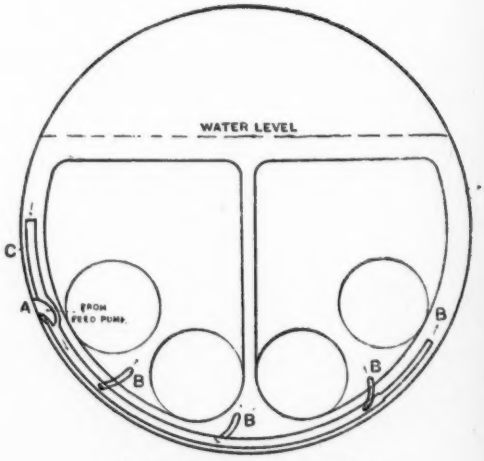


Fig. 2.—Section of Marine Boiler.

can no longer be allowed to exist without imperiling the structure through the stress brought by the unequal expansion of the parts, and it is to the proper and best method of introducing this feed water (be it hot or cool) that much attention is now being given by all steam users, and more especially by those engaged in marine work, for even the hottest feed water may be introduced so as to fall in its best point—that of aiding in producing a good circulation. This feature has been too frequently overlooked by those who have adopted the use of feed-water heaters, and thought that included all the needed precautions; but it is as much an element of life to the boiler, or even more so, than sending the feed in hot; for where, by reason of bad or faulty design, a good natural circulation does not exist, that portion of the heating surface which properly should be most efficient is deprived of the close and constant supply of water, and soon becomes burnt and leaky, or even dangerous. Many ruined crown sheets and tube ends owe their failure to this defect rather than to high furnace temperature or cold feed.

It behooves, therefore, every user of steam boilers, either ashore or afloat, to satisfy himself that he is not injuring his boilers nor wasting his costly coal pile through a defective feed system and faulty circulation, and while a good natural circulation is almost impossible to provide for in multitubular boilers, an effective artificial one is not difficult to arrange. He must keep in mind that simply deflecting the feed downward by an internal bend is not effective, for while it does provide against the direct impingement of cool water upon very hot surfaces, it at the same time sends the cool water to that part of the boiler already cooler than the rest and fails to help matters. This faulty practice existed until only recently with very prominent builders and designers, but has been summarily dropped except by those too careless of principles. Too much cannot be said in favor of the feed-water heaters, the benefit and profit accruing from their use being far reaching and great; but these are often difficult to apply to a large plant in close quarters, and the two devices here illustrated embody heating features as well as circulating ones, and are well worthy of careful study, especially as to principle. Anyone can

modify and apply these points to their boiler feed pipe, according to need, and few boilers would fail to be improved by it.

Figs. 1 and 2 show the most recent arrangement of internal pipes for feeding marine boilers, and are equally applicable where outside heaters are or are not used. The general idea of each is to induce a transfer of water from the top to the bottom, or *vice versa*, by the current of the entering feed, to have the induced stream mix with the feed while still in the pipe, and to distribute the thus heated water uniformly and at various points through small branches whose aggregate area slightly exceeds that of the main. In that shown in Fig. 1 the entering water is directed upward through an injector nozzle, A, Fig. 3, which is contained within the pipe, and as the stream rushes upward it induces another stream through the connecting pipe C, which takes its water from the very bottom of the boiler by a perforated branch running longitudinally there. This induced stream mingles with the feed, and is carried up over the tops of the tubes, through the hottest water, and is delivered by the small branches B B B downward between the tube nests. This is a forced circulation, which is obviously excellent, and has been successfully adopted by one of the largest ship-building firms in the country, who originated it.

The next device, Fig. 2, is probably even a better plan, and is just the reverse of the first in its operation. The feed here is directed downward by a similar nozzle, and the induced current is drawn from the hottest water nearer the top. This mingled feed is thus greatly heated, and is delivered at the bottom of the boiler through small branches directed backward and upward toward the back tube sheets, the most important point to have well supplied with water. The latter plan is somewhat on the principle of the circulator used on the French cruiser *Forbin*, though much simpler. There a small metal-valved pump was attached to each boiler solely to draw water out from about the level of the top of the furnaces and deliver it into the very bottom, thus positively preventing the settlement of a body of cooler water there, and proving extremely successful as a circulator and preserver of heating surfaces. When it is realized what an

enormous quantity of feed water is required by a single one of the larger marine boilers, it is not difficult to understand the effectiveness of the stream, if properly directed, as a circulator, and the importance attached to the operation. For instance, one modern eight-furnace boiler (double ended) with usual size grates will, under forced draft, require about twenty tons of feed water per hour.

U. S. REVENUE STEAMER *WILLIAM WINDOM.*

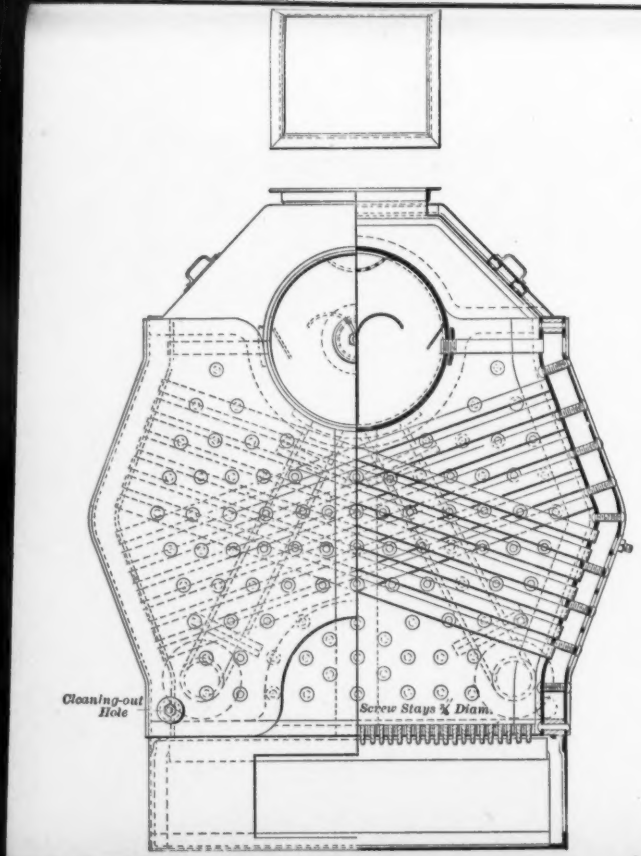
The accompanying illustrations are of the engines and boilers for the U. S. revenue steamer *William Windom* (twin screw), now in course of construction at the Iowa Iron Works, of Dubuque, Iowa. The steel plates for her hull were made by the Carbon Steel Co., of Pittsburgh, Pa.

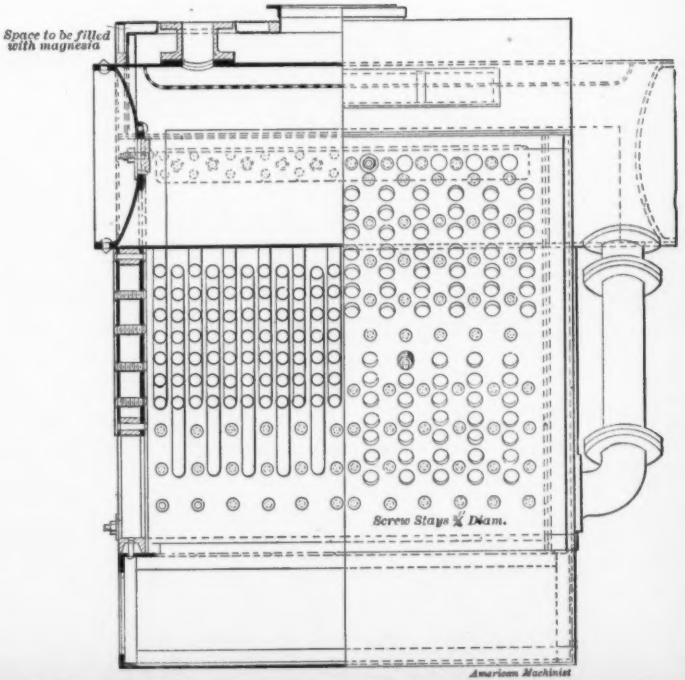
The propelling engines are right and left, placed in a common water-tight compartment. These engines are of the vertical, inverted-cylinder, direct-acting, triple-expansion type, each with a high-pressure cylinder 11¾ inches, an intermediate pressure cylinder 16½ inches, and a low-pressure cylinder 26½ inches in diameter; the stroke of all pistons is 24 inches. The collective indicated horse power of propelling, air-pump, and circulating-pump engines will be about 800 when the main engines are making 175 revolutions per minute. The high-pressure cylinder of each engine is placed forward.

The piston rods are of forged steel 2⅝ inches diameter, excepting at the ends, where they will be 2¼ inches diameter over threads. The collar at piston end is 3¼ inches diameter and ½ inch thick, and recessed in the piston. The crosshead end of the piston rod is forged so as to form the crosshead slipper and the bearing for the crosshead journal, the latter being carried by the connecting rod. The butt brass is ½ inch thick, and the cap brass forms the binder. The binder bolts are 1½ inches diameter.

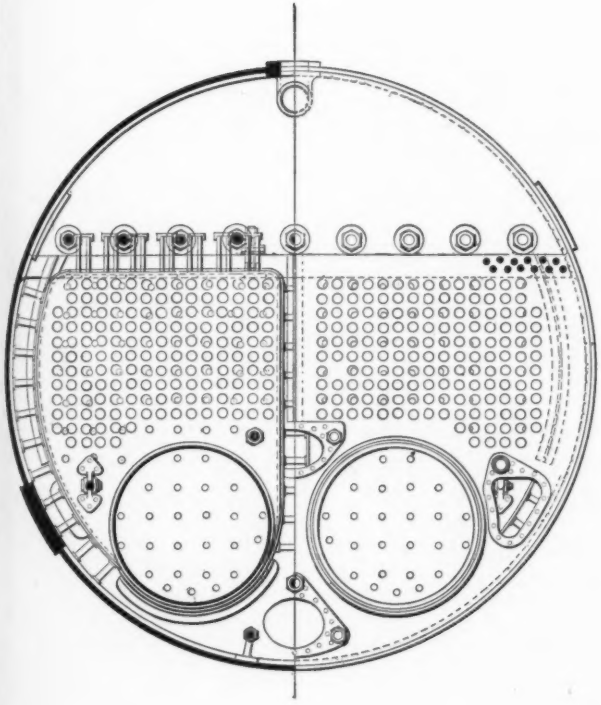
The slipper is 10 inches long and 8 inches wide, 1 inch thick at the sides, increasing to 1½ inches at the center. It is lined with transverse bars of white metal.

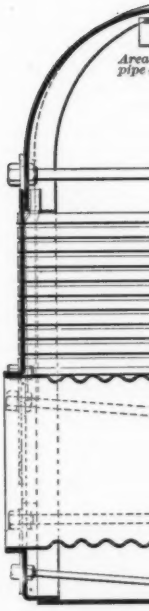
The crosshead guide is of cast iron, fitted for water circulation. The connecting rods, with their bolts, are of forged steel. Length of connecting rod, 60 inches between centers, turned to 2½ inches in diameter at the small end and 3¼ inches at the large end. Bolts 1½ inches diameter.

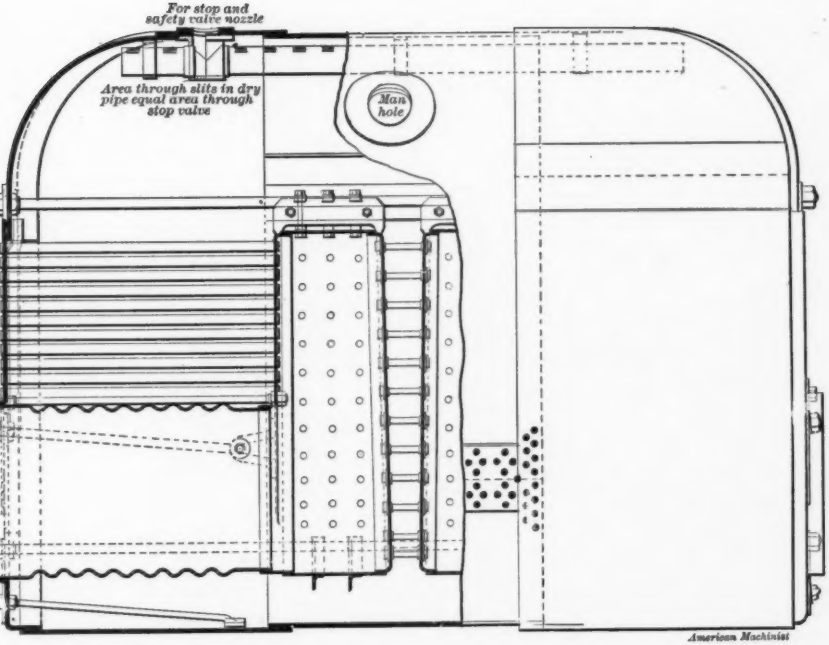

Cleaning-out Hole
Screw Stays ⅞ Diam.

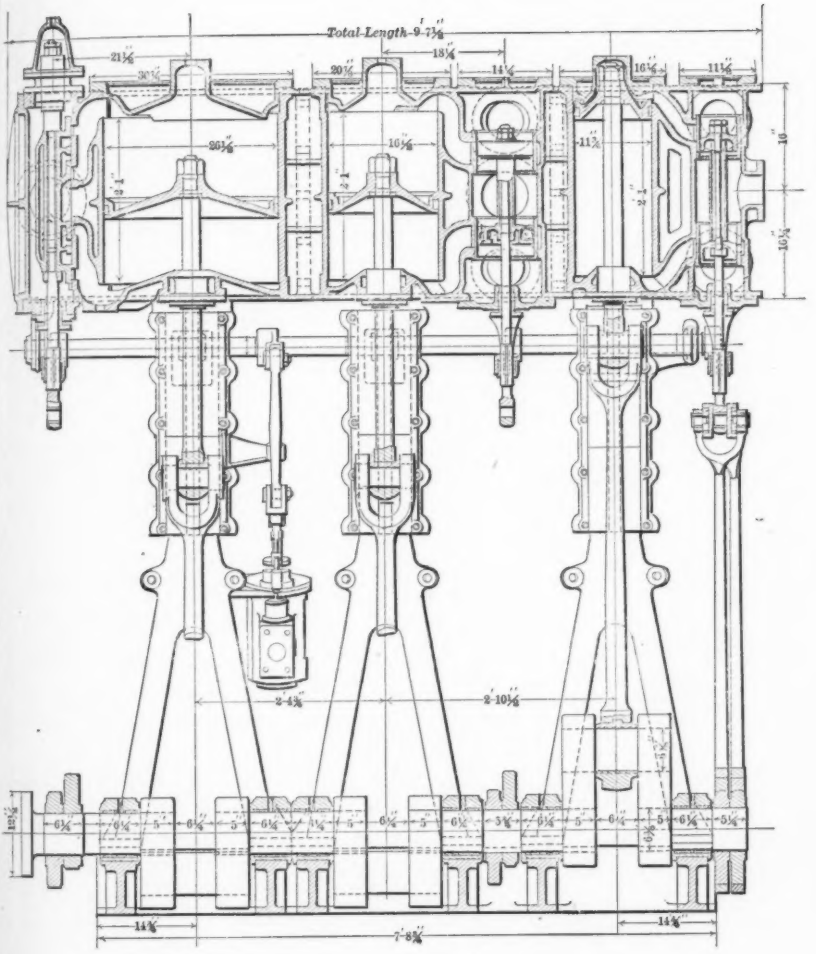

Space to be filled with magnesia
Screw Stays ⅞ Diam.
American Machinist

XU






For stop and safety valve nozzle
Area through slits in dry pipe equal area through stop valve
Man hole
American Machinist


Total Length 9'-7⅞"
18¼"
21¼"
30"
20"
14¼"
16¼"
11¼"
26⅞"
16¼"
11⅞"
16"
10¾"
2'-4"
2'-4"
2'-4"
2'-4⅜"
2'-10⅛"
12¾"
6¼"
6¼"
5"
6¼"
5"
6¼"
5"
6¼"
5"
6¼"
5"
5⅛"
6¼"
5"
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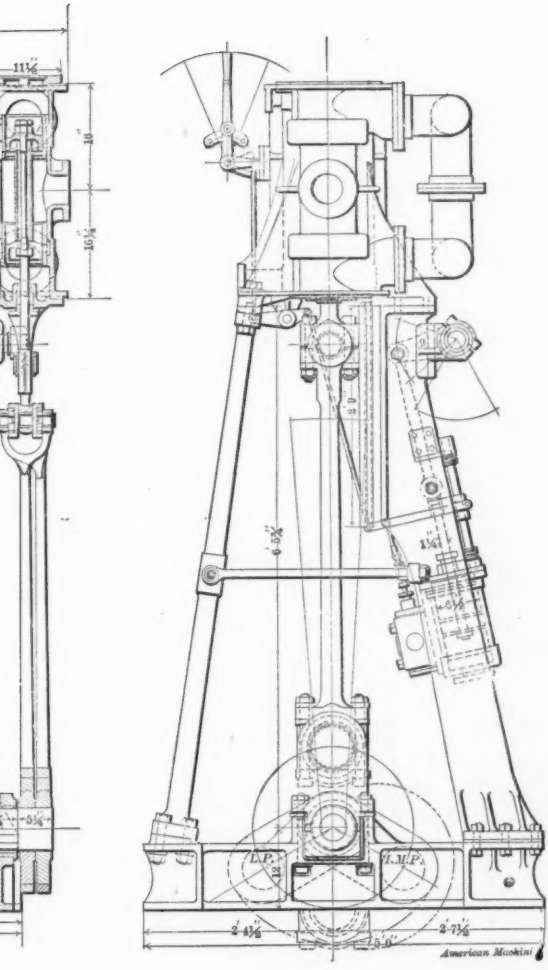
5"
6⅜"
6¼"
5¼"
14⅛"
7'-8¾"
14⅛"


11¼"
10"
10¼"
6-5½"
1¼"
0¼"
0¼"
L.P.
H.P.
2'-4⅛"
5'-0"
2'-7⅛"
American Muskini

The valve gear is of the Stephenson type, with double bar links. All valves are worked direct. The valve gear is so adjusted that the mean cut-off in full gear for both ends of each cylinder is about 0.7 stroke. There are piston valves for the high-pressure and intermediate cylinders, and slide valves for the low-pressure cylinders. The piston valve consists of two hollow pistons, made to fit the valve liners accurately without packing rings for the H.P. valves and with packing rings in I.P. chests. The diameter of the H.P. valve is $5\frac{3}{4}$ inches and the I.P. valve is $8\frac{1}{2}$ inches diameter.

The hollow pistons of each valve are separated by steel distance pieces of such a length as to make the steam and exhaust laps for the H.P. and I.P. valves as follows: Steam lap at top, 1 inch; at bottom, $\frac{29}{32}$ inch; exhaust lap, top, minus $\frac{1}{32}$ inch; bottom, minus $\frac{5}{64}$ inch. The steam ports of the high and intermediate-pressure cylinders are $1\frac{1}{2}$ inches wide, and the diagonal bridges take up not more than one-quarter of the total port area. The low-pressure cylinder has a double ported cast-iron slide valve; steam lap on top, 1 inch; bottom, 1 inch; exhaust lap, top $\frac{7}{32}$ inch; bottom, $\frac{1}{2}$ inch; steam ports, $1\frac{1}{2}$ inches wide.

A $5\frac{1}{2}$-inch pipe leads from each end of H.P. valve chest to the corresponding end of the I.P. valve chest, with a connecting pipe; a 7-inch pipe leads from the I.P. exhaust to L.P. chest, and a 9-inch pipe from the L.P. exhaust to the condenser.

The crank-shaft journals at each side of the cranks are $6\frac{1}{4}$ inches diameter and $6\frac{1}{4}$ inches long. The crank-pins are $6\frac{1}{4}$ inches diameter and $6\frac{1}{4}$ inches long. The thrust shafts are $6\frac{1}{4}$ inches diameter. Each shaft has eight thrust collars $1\frac{1}{4}$ inches thick, with spaces of 2 inches; the collars are $9\frac{1}{4}$ inches outside diameter.

The main condenser is made cylindrical, 3 feet 6 inches internal diameter, made of wrought iron $\frac{5}{16}$-inch thick, with welded seams. It contains 1,590 seamless tubes $\frac{5}{8}$-inch outside diameter, No. 18 B.W.G., in thickness, tinned outside and inside. The tubes are 5 feet $1\frac{1}{2}$ inches long between tube sheets. The cooling surface is about 1,333 square feet, measured on outside of tubes.

The air and circulating pumps are of the combined type, and independent of the main engines.

Steam is supplied by one double-ended cylindrical Scotch boiler. Outside diameter, 12 feet $2\frac{3}{32}$ inches; length over heads, 16 feet 4 inches; length of grate, 6 feet. Total heating surface, 2,415 square feet; grate surface, 76 square feet; ratio of heating to grate surface, 31.78; thickness of boiler shell, $1\frac{3}{64}$ inches; boiler pressure, 160 pounds.

There is also an auxiliary boiler of the description known as the Towne patent. Its grate surface is 9.4 square feet; total heating surface, 259.6 square feet. Its total height to top of uptake is 5 feet 4 inches, including ash pit, and its outside dimensions, exclusive of clothing, are 4 feet 3 inches by 3 feet 8 inches. The drum is 18 inches outside diameter, 4 feet 8 inches long, and $\frac{5}{16}$ inch thick.

The principal dimensions of the hull are:

Length over all, feet and inches	170–8
Length, extreme on water line, feet	160
Breadth of beam, molded, feet	27
Breadth of beam, extreme, feet and inches	27–$1\frac{1}{2}$
Depth of hold amidships at dead-flat frame from top of floor stringer plate to top of main-deck beam, feet and inches	13–5
Draught, mean, with 50 tons of coal in bunkers, feet and inches	6–6
Displacement at 6 feet 6 inches mean draught, tons	412

—"American Machinist."

A SIMPLE GRAPHIC METHOD OF CONSIDERING THE OBLIQUITY OF CONNECTING RODS IN VALVE DIAGRAMS.

[Translated from the French.]

By Albert E. Guy, Esq., Associate.

The valve diagrams of Reuleaux, Reech, Zeuner and Marcel Deprez give very simply approximate results which suppose the connecting rods infinite; but as the obliquity of the latter can rarely to be neglected, it becomes necessary, to obtain correct results, to make a diagram of the piston path either by means of beam compasses or by using cardboard models having for radii the lengths of the rods.

Mr. F. Dubost, an engineer connected with the Eastern Railway Company of France, has recently made known a valve diagram which, without approximations and limiting the drawing to the circle described by the crank pin, gives results rigorously correct.

Mr. Dubost has given elegant geometric demonstrations which permit the determination of the corresponding positions of the crank pin and of the other end of the connecting rod.

FIRST DEMONSTRATION.

Let us consider (Fig. 1) a crank, R, in two positions, AB ab, equally inclined upon the line of motion AI of the extremity of the connecting rod L. The corresponding positions of the rod are BI and bi. The figure Bb Ii is a parallelogram, and by drawing BC bc perpendiculars to AI, we have

$$CA = Ac - BC = bc$$

$$Cc = Bb = Ii = 2CA$$

$$AI = CI - CA = \sqrt{\overline{BI}^2 - \overline{BC}^2} - CA$$

$$Ai = Ci + Ac = \sqrt{\overline{bi}^2 - \overline{bc}^2} + Ac.$$

From this is deduced the product of the distances $AI\ Ai$, since

$$BI = bi = L$$

$$\overline{BC}^2 + \overline{CA}^2 = R^2$$

$$AI \times Ai = \overline{BI}^2 - (\overline{Bc}^2 + \overline{CA}^2) = L^2 - R^2.$$

Then the product $AI \times Ai$ of the distances from the axis to the extremity of the connecting rod corresponding to two positions of the crank pin symmetrical to the axis normal to the line of motion is constant and equals $(L^2 - R^2)$.

At the dead points, the end of the rod occupies the positions D and d (Fig. 2). Let us describe on $Dd = 2R$ as diameter, a circumference of center o. If AM is a tangent to this circumference, then

$$AD \times Ad = AI \times Ai = \overline{AM}^2 = L^2 - R^2.$$

And if, on AO, we take $AP = AM$ and join MP (Fig. 2), which, produced, meets the circumference Dd at E, angle AMP measures

$$\left(\frac{\text{Arc } MD + \text{arc } DE}{2}\right)$$

angle APM measures

$$\left(\frac{\text{Arc } MD + \text{arc } Ed}{2}\right)$$

and as angle AMP = angle APM, it results that arc DE = arc Ed, that is to say, the line MP passes through the middle point E of the circumference DEd.

This line MP is also bisectrix of all the angles IMi. Effectively let us join M to a point G on AO, such that MP bisects angle IMG, and describe from A as center, and AM as radius, a semi-circumference cutting AO at a second point p; Mp will bisect the supplement of angle IMG since $PMp = 90°$, as being inscribed in a semi-circumference.

We have, then,

$$\frac{IM}{MG} = \frac{IP}{PG} = \frac{pI}{pG} = \frac{AP - AI}{AG - AP} = \frac{Ap + AI}{Ap + AG} = \frac{AP + AI}{AP + AG} = \frac{2\,AP}{2\,AG} = \frac{2\,AI}{2\,AP}$$

and therefrom

$$AI \times AG = \overline{AP}^2 = L^2 - R^2 = AI \times Ai,$$

which shows that $AG = Ai$, and demonstrates the coincidence of points i and G, *or that line MP is bisectrix of all the angles IMi.*

Fig. 1.

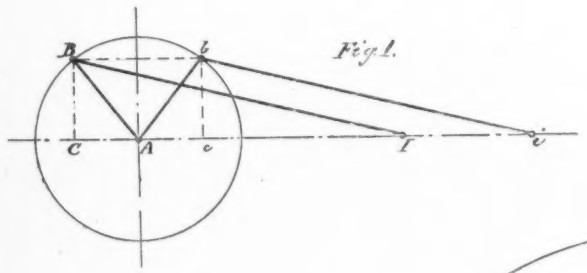


Fig. 4.

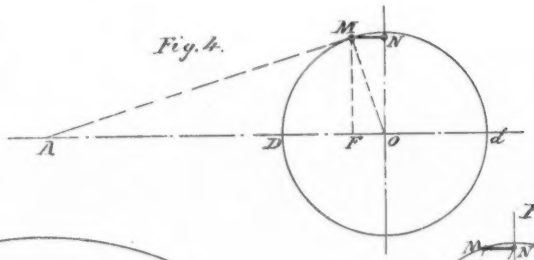


Fig. 5

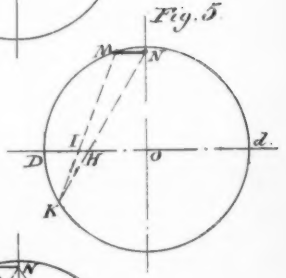


Fig. 3.

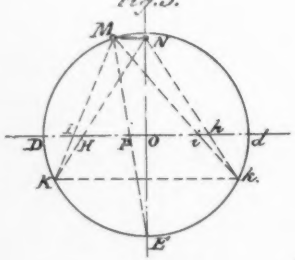


Fig. 2.

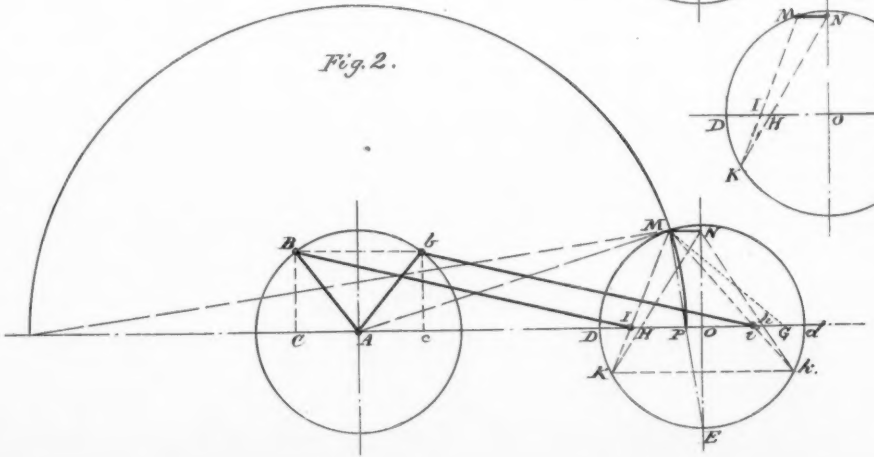


Fig. 8.

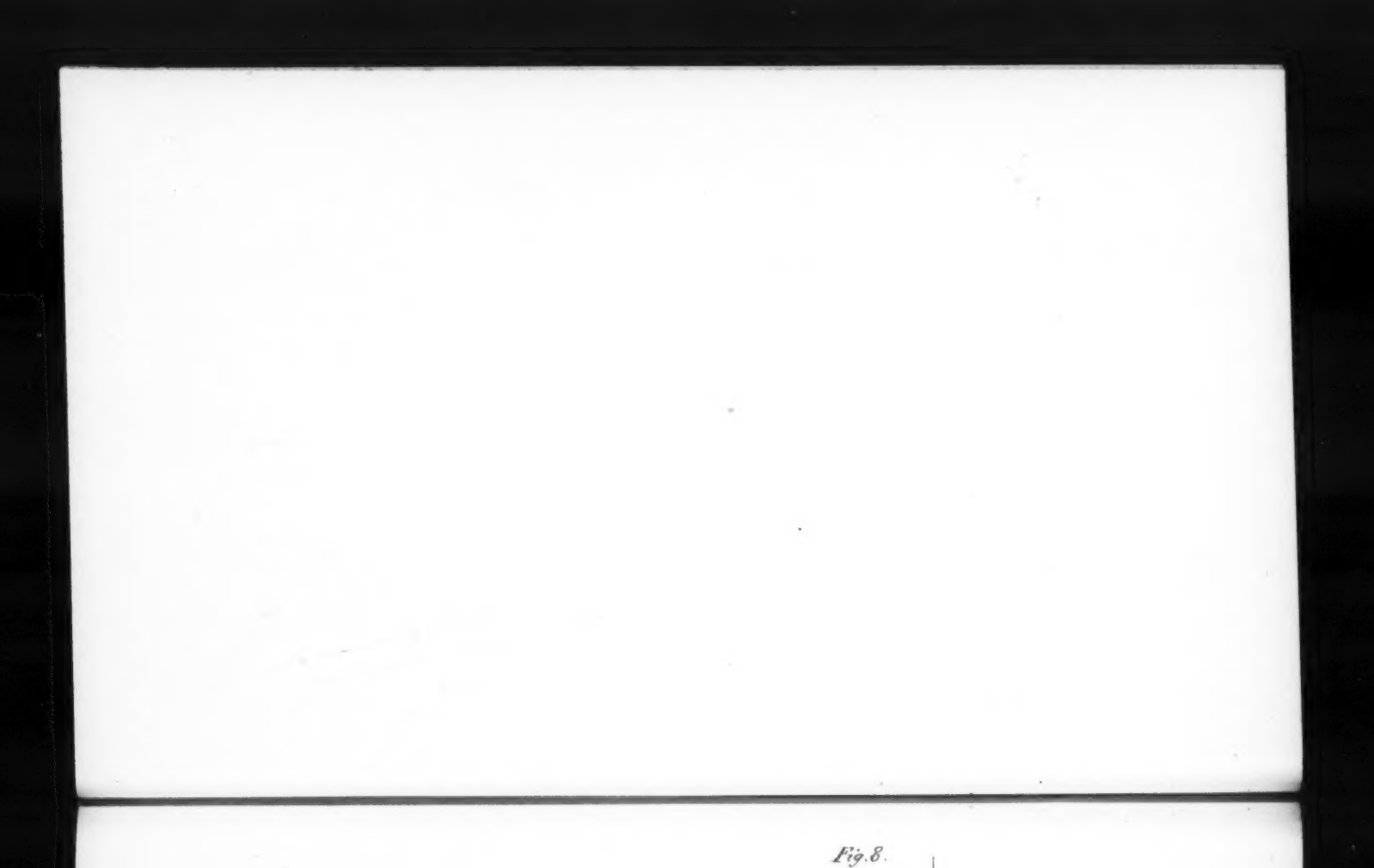


Fig. 6.

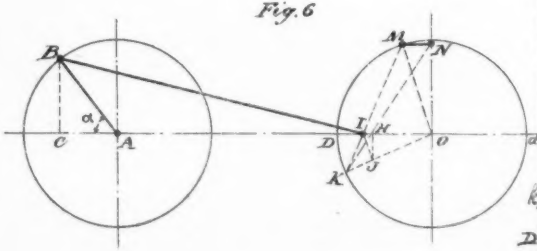


Fig. 7.

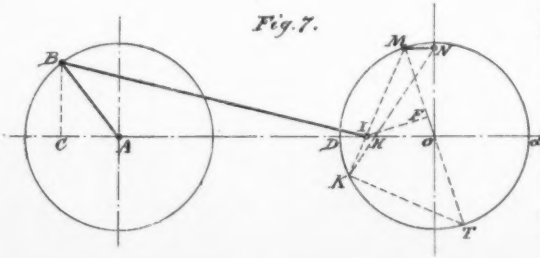
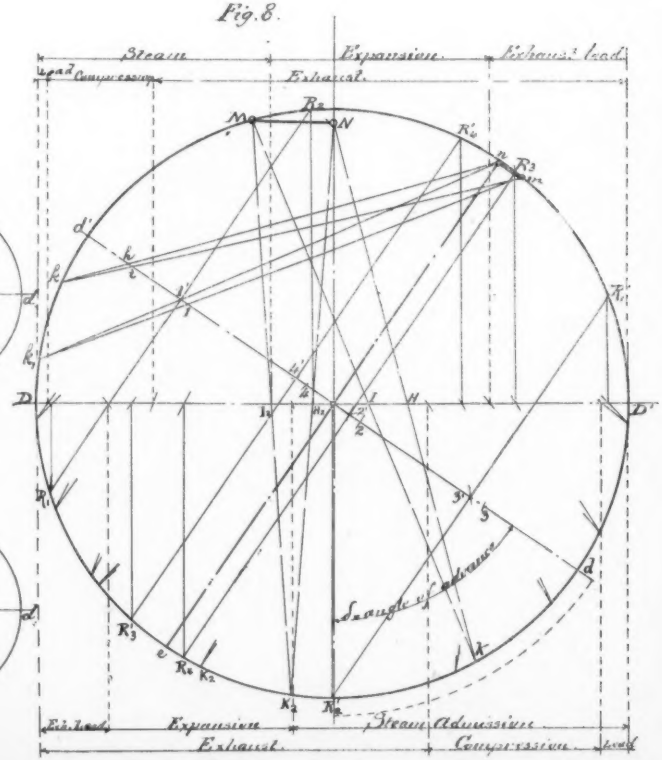


Fig. 8.



Through M let us draw a parallel to diameter Dd, cutting the perpendicular diameter at N (Figs. 2 and 3), and join this point to the intersections K and k of MI and Mi with the circumference; the lines NK, Nk will cut Dd at H and h. The line MPE bisecting angle KMk, arc $KE =$ arc Ek, and Kk is parallel to Dd and to MN.

Then we have

$$Hh = Ii = Cc. \quad OH = Oh = AC = Ac. \quad AO = CH = ch = L.$$

It follows that the points H, h can be considered as the projections C, c of the crank pin, transported the length of the connecting rod parallell to the line of motion, and also as corresponding respectively to the positions I and i of the extremity of the rod.

The corresponding points, I joined to M, and H joined to N, give two lines meeting at K on the circumference of center o with a diameter $= 2R$; the same applies to points i and h.

If MN is projected at OF (Fig. 4) on the hypothenuse OA of the right triangle AMO, we have

$$MN = OF = \frac{OM^2}{AO} = \frac{R^2}{L}.$$

From the foregoing comes the following kinematic property, which enables us to determine simply and rigorously the position of the crank pin from that of the other end of the rod, and *vice versa*.

For a connecting rod of length L and a crank, R, the reciprocal positions I of the extremity of the rod and H of the projection of the of crank pin on the direction of motion, displaced in this direction the length of the rod are found by joining the extremities M and N of a semi-chord equal to $\frac{R^2}{L}$ *parallel to the line of motion with a point, K, traveling on the half circumference opposite the semi-chord* (*Fig. 5*).

This result, once known, may be directly established in several ways, viz:

SECOND DEMONSTRATION.

The distance AI is, calling α the angle of rotation (Fig. 6),

$$AI = -R\cos\alpha + \sqrt{L^2 - R^2\sin^2\alpha}.$$

If the projection C of the crank pin is carried a distance L to H, then

$$IH = L - \sqrt{L^2 - R^2 \sin^2 a}.$$

Then if the semi-chord $MN = \frac{R^2}{L}$ and points M and N joined to a point, K, anywhere on semi-circumference DEd, we must demonstrate that the intersections I and H of lines MK NK with Dd give simultaneous positions of the end of the rod and of the projection of the crank pin. It suffices for that to show that if $IH = L - \sqrt{L^2 - R^2 \sin^2 a}$, then $OH = AC - R \cos a$, and *vice versa*. Effectively let us draw HJ parallel to ON, and, cutting OK at J, IJ is evidently parallel to OM and also equal to KJ.

The similar triangles IJH, MON give

$$\frac{IJ}{IH} = \frac{MO}{MN} = \frac{L}{R}, \text{ thence } IJ \times R = IH \times L.$$

But on account of the right triangles OHJ, HIJ,

$$OH^2 - OJ^2 = HJ^2 = (OK - KJ)^2 - (IJ^2 - IH^2),$$

and as $OK = R$, $KJ = IJ$,

$$\begin{aligned} OH^2 - R^2 &= -(2R \times IJ) + IH^2 \\ &= R^2 - (2L \times IH) + IH^2 \\ &= R^2 - L^2 + (L - IH)^2; \end{aligned} \qquad (1)$$

thence, if $IH = L - \sqrt{L^2 - R^2 \sin^2 a}$,

$$\begin{aligned} OH^2 &= R^2 - L^2 + (L - L + \sqrt{L^2 - R^2 \sin^2 a})^2 \\ &= R^2 \cos^2 a. \end{aligned}$$

Vice versa, if

$$OH = R \cos a,$$

from (1) we get

$$\begin{aligned} (L - IH)^2 &= L^2 - R^2 \sin^2 a \\ IH &= L - \sqrt{L^2 - R^2 \sin^2 a}. \end{aligned}$$

THIRD DEMONSTRATION.

(Fig. 7.) The semi-chord MN is supposed equal to $\frac{R^2}{L}$, let us join MI, which we suppose drawn, until it meets the circumference at K. We must demonstrate that the three points N, H, K, are in straight line, H being the projection of the crank pin displaced the length of the rod.

In the circle, o, we have:

$$\begin{aligned} MI \times IK &= R^2 - OI^2 \\ &= R^2 - (AO - AI)^2 \\ &= R^2 - (BI - AI)^2 \text{ since } AO = BI. \end{aligned} \tag{2}$$

But in triangle ABI:

$$\begin{aligned} AB^2 = R^2 &= BI^2 + AI^2 - 2\,AI \times CI \\ &= BI^2 + AI^2 - 2\,AI\,(CH - IH) \end{aligned} \tag{3}$$

and as $CH = BI$, we get by adding (2) and (3):

$$MI \times IK = 2\,AI \times IH. \tag{4}$$

Now, if IF made perpendicular to MO, drawn until it meets the circumference at T, and KT are joined, the lines IF and KT parallel to MK and MT give, since:

$$\frac{OF}{OI} = \frac{MN}{OM}, \quad OF = OI \times \frac{R}{L}$$

$$\begin{aligned} MI \times MK &= MF \times MT \\ &= (R - OF) \times 2\,R \\ &= \left(R - OI \times \frac{R}{L}\right) \times 2\,R \\ &= \left[R - (AO - AI) \times \frac{R}{L}\right] \times 2\,R. \end{aligned}$$

But $AO = L$, then

$$MI \times MK = 2\,AI \times \frac{R^2}{L} = 2\,AI \times MN. \tag{5}$$

Dividing (4) by (5) we have:

$$\frac{IK}{MK} = \frac{IH}{MN}$$

Which shows that the three points N, H, K, are on a straight line and proves the exactitude of the kinematic proposition.

Let us now apply this kinematic propriety to a real diagram of the crank, piston, eccentric and valve path.

We have a piston connected to a crank, R, by a rod, L; a steam valve connected to an eccentric of radius, r, by a rod, l. The eccentric is set at an angle (δ) from the crank. The crank revolves from left to right, but we will place the eccentric in the opposite direction at an angle $= 90° + \delta$.

The direction of the eccentricity coincides then with that of the crank, and the valve motion takes place along dd', forming

with DD', line of piston motion, an angle $90° + \delta$ (Fig. 8). For simplicity, the scale of the eccentric circle will be such that $r = R$.

The semi-chords

$$mn = \frac{r^2}{l}, \quad MN = \frac{R^2}{L}$$

respectively parallel to dd' and DD' once drawn, the intersections i and h of lines mk, nk joining m and n to a point k of the semi-circumference ded' will determine on dd', as per demonstrations, reciprocally the position of the crank pin or center of the eccentric projected on dd', and that of the end of the valve rod.

Similarly we will get the projection of the crank pin and position of piston at any period of the stroke by the intersections I and H on DD' of the lines MK and NK joining M and N to a point K on the semi-circumference DED'.

O is the center of oscillation of the valve. The steam port opens when the valve has traveled towards Od' a distance $O1$ = the outside or steam lap. The port will be closed when the valve comes back to 1, after having gone to d'.

Now, mark off on dd' from O the lap $O1$. When the valve is at 1 the eccentric center is at 1_1 intersection of dd' with the line nk_1 joining n to the intersection k_1 of $m1$ with the circumference of radius r. Through $1'$ let us draw a perpendicular to dd'. It will cut the circumference at R_1, R_2, and OR_1 OR_2 will be the positions of the crank for the lead and cut-off.

The valve travels towards $d'd$ a distance $O2$ = the inside or exhaust lap; the exhaust opens at that point and closes there on the return stroke. Drawing $m2$ until it cuts the circumference at k_2, intersection 2_1 of nk_2 with $d'd$ gives the projection R_3 R_4 of the eccentric center, and subsequently the positions OR_3 OR_4 of the crank corresponding to the exhaust lead and compression.

The other end of the valve may be treated in the same way, and crank positions OR'_1, OR'_2, OR'_3, OR'_4 determined.

If the obliquity of the valve rod could be neglected, the positions of the crank would be given by joining the center O to the

intersections of perpendiculars to $d'd$ drawn through points 1, 2, 3, 4 with the circumference.

The crank positions exactly determined, the corresponding positions of the pistons are therefrom rigorously deduced. The points R_1, R_2, R_3, R_4 must be projected on DD'. The position OR_2, for instance, gives point H_2, which, joined to N, determines K_2 on the circumference. Intersection I_2 of MK_2 with DD' shows the position of the piston at cut-off, and so on.

The graphic execution of the diagram of Mr. Dubost requires only the use of straight lines cutting each other at angles equal to or greater than about 45 degrees.

Unlike the diagram of Zeuner, this diagram is exact, and for the case of very small inside lap it shows its exactness best.

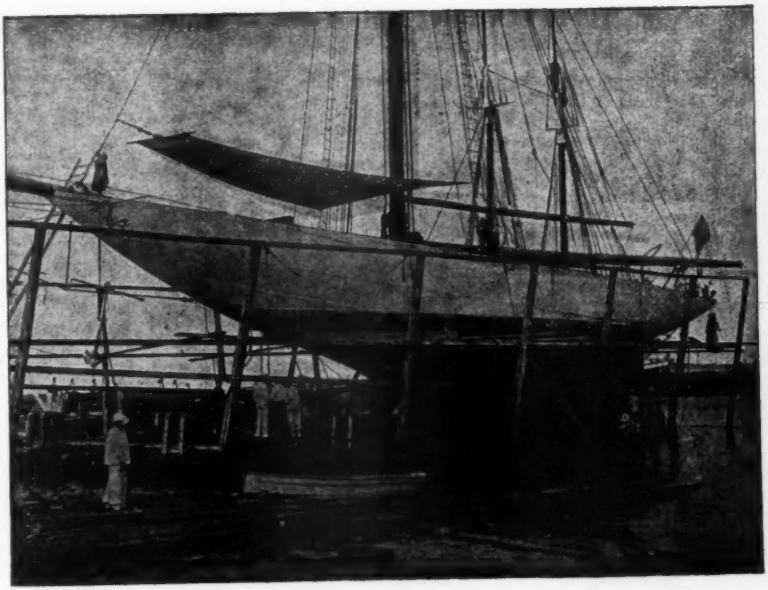
THE 1893 CONTEST FOR THE *AMERICA'S* CUP.

Through the courtesy of W. P. Stephens, Esq., yachting editor of "Forest and Stream," the JOURNAL is able to present the following account of the international contest for the *America's* cup, which took place last month, consisting of extracts from Mr. Stephens' articles.

THE CUP DEFENDERS OF 1893.

	Vigilant.	*Colonia.*	*Jubilee.*	*Pilgrim.*
Owners	C. O. Iselin *et al.*	Arch. Rogers *et al.*	Gen. Chas. J. Paine.	R. S. Palmer *et al.*
Designer	N. G. Herreshoff.	N. G. Herreshoff.	John B. Paine.	Stewart & Binney.
Builder	Herreshoff M'f'g Co.	Herreshoff M'f'g Co.	Lawley Co.	Pusey & Jones.
Type	Keel centerboard.	Keel.	Bulb-fin centerboard.	Bulb fin-keel.
Rig	Cutter.	Cutter.	Cutter.	Cutter.
Length over all	128 feet.	126 feet.	123 feet.	120 feet.
Length load water line	86.12 feet.	85.48 feet.	84.47 feet.	85.28 feet.
Beam	26 feet.	24 feet.	22 feet 6 inches.	23 feet.
Draught	14 feet.	13 feet 9 inches.	14 feet.	22 feet.
Sail area	11,312 square feet.	11,355 square feet.	11,340 square feet.	10,269 square feet.
Actual racing length	96.24 feet.	96.02 feet.	95.48 feet.	93.31 feet.
Amended racing length	96.80 feet.	96.26 feet.	95.48 feet.	93.45 feet.
Allowance 30 nautical miles	Allows.	14 seconds.	37 seconds.	1 minute 39 seconds.

The allowances are calculated on the basis suggested by Lord Dunraven, that any yacht exceeding the limit of 85 feet load-water line by more than 2 per cent. shall be disqualified from racing, and that any excess under 2 per cent. shall be doubled. Thus, *Vigilant* is 86.12 feet, or 1.12 feet over the limit, her water line being assumed as 87.24, or 2.24 feet excess in place of 1.12 feet. *Jubilee* is the only one of the four which escapes a penalty by being under the limit. *Valkyrie* will probably be penalized a little in the cup races.



"VIGILANT."

On page 650 of the current volume an account was given of the vessels which competed for the honor of defending the cup, but it was necessarily incomplete and the dimensions approximate. The actual dimensions are given on the preceding page.

Mr. Stephens discusses the cup defenders as follows:

There is perhaps nothing which could contribute more to the successful growth of American yachting than a keen but friendly rivalry between the two great yachting centers; but to be of any benefit such a rivalry should be based on the merits of local designers and builders, and not on the mere ownership of boats from the same locality. It is a reproach to New York that with all her claims of leadership and her old-time reputation in all branches of marine architecture, her home-built boats have completely disappeared from the Cup contests. So far as the local issues are concerned this year they are interesting to those immediately connected with the various yachts.

The technical issues are more clearly defined and of far greater importance, and it is a matter for regret that owing to the lack of early preparation it is now doubtful whether the full benefits will be obtained from a most expensive experimental fleet. If the present trial races could be followed by a short period for necessary alterations and then a month of hard racing, the merits and defects of the four different types might be closely determined, but it seems almost certain now that the season will end with a few more trial races, in which few conclusive results will be reached, and that by next season the four will have disappeared from racing, the class dying out again, or in the event of its continuance, the present boats being outbuilt during the winter. The four types may be classed as follows:

Keel cutter.
Keel-centerboard cutter.
Bulb-fin keel.
Bulb-fin centerboard.

Half a dozen years since this lingo would have been Greek to the most experienced yachtsman, but to-day any ten-year old boy who lives within three miles of Long Island Sound could give a full explanation of it.

Colonia is the first keel boat built to defend the America's Cup, although the old yacht herself has always been a keel boat, and a number of keel schooners have sailed at times in the fleets which have been opposed to two of the various challengers. In model *Colonia* has nothing in common with the old yachts of

either side, the narrow cutter or the shallow sloop, but her form is the result of a general process of evolution carried out in common by American and British designers for the last four years. The main points of this development, the reduction of displacement and frictional surface, are directly traceable to the tax on sail imposed by the new Y. R. A. rating rule which replaced the tonnage rule in 1886 in England, the influence in these directions being slight at first, but strongly felt about 1890 and increasing ever since.

The return of the Herreshoffs to the designing of sailing yachts, in 1891, is marked by the feature of extreme beam and draught with reduced displacement in *Gloriana*, and in the fall of the same year, in *Dilemma*, by the adoption of the canoe-shaped hull and fin keel in a new and extreme form, the fin being, instead of a thick lead keel with the deadwoods fore and aft omitted, a thin plate of steel with the weight of ballast concentrated at the lowest possible point in the form of a lead bulb or cigar affixed to the bottom of the fin.

Radical as were these departures from the then popular form, they were accompanied by a still more extreme feature in the abnormal fullness of the water lines, accompanied by long, clean and easy diagonals and section lines, leading to a great length of overhang at each end. A careful study of the successful racing yachts, American and British, of the last four or five years will show that while *Gloriana*, *Wasp* and *Dilemma* combine more extreme features than any other yachts, these features by no means originate exclusively in them, but are the results of a clearly-marked course of evolution in which each of the leading designers has taken part, the result being a very close agreement in dimensions, models and what are popularly classed as "freak" features in all of the recent racing yachts.

Colonia, like her prototype *Wasp*, represents but a medium stage in this extreme development, possessing the long, easily-lined hull and the overhanging ends, but with the fin only partially developed, representing an intermediate stage between the wide cutter, such as *Thistle* or the first *Valkyrie*, and the pure fin keel. While allied to the older cutters in construction, her frames and plating running down to the trough keel, at the same time the deadwood at the fore end is freely cut away, and the lower part of the hull is thin and deep, approaching closely the fin, while the outside lead keel is considerably bulbed.

Although the depth of this fin is considerably in excess of the draft of the older cutters, the total draft of *Colonia* being about 15 feet 9 inches, while *Thistle*, *Genesta* and *Galatea* drew just 13

feet each, it by no means approaches the proportional draft of the successful keel boats, such as *Minerva*, *Gloriana* and *Wasp*. The proper draft for a given length and sail area is hardly a matter of exact calculation, any more than the sail area is, but figures are at least useful as a basis of comparison. In the 40-foot and 46-foot classes the ratio of draft to waterline ranges from 23 per cent. in the low-powered boats like *Minerva*, to about 26 per cent. in the high-powered, an increase of lateral resistance of course accompanying a larger sail plan. In the older of the large cutters, all of which have failed to windward beside the deep centerboard boats, the ratio is as low as 15 per cent., a very low figure, even after a liberal allowance for the reduced proportion of draft which accompanies the doubling of the waterline length. In *Colonia* the ratio, in spite of her high power, is only 18½ per cent. or little more, in proportion to her power, than in *Thistle*.

Compared with *Thistle*, the lateral plane of *Colonia* is vastly more effective, presenting a flat side of considerable depth in place of easy-flowing curves; but compared with *Wasp*, of similar form and power, the proportion of draft is far less than the figures would indicate as necessary, perhaps 21 per cent., or a total draft of 18 feet. While these figures and conclusions may be crude and incomplete, they at least indicate a line of thought which may be profitably followed in estimating *Colonia's* importance as an exponent of the keel type.

The other Herreshoff boat, *Vigilant*, is of the same general form, the exact difference being best indicated by the dimensions, some 2 feet more beam, 2½ feet less draft, and the addition of a centerboard, the displacement being less by some 15 tons. One important difference between the two is the material of the skin. *Vigilant* being plated with Tobin bronze, a smooth and non-corrosive alloy while *Colonia*, like the two Boston boats, is plated with steel.

The most extreme of the four is the bulb-fin *Pilgrim*, a boat of small displacement and easy form, not unlike a canoe, the draft of hull being but 5 feet, while beneath it is a depth of fin of 17 feet. At the bottom of this fin, which in itself weighs some 15 tons, is the lead bulb of about 17 tons, its length being about 18 feet. The yacht has no centerboard, relying entirely on her keel for lateral resistance.

The fourth boat is less extreme than *Pilgrim* but no less odd and interesting; the hull is similar in general form, but of greater displacement and with fuller lines, especially aft, while the ends are much blunter. The fin is similar in form and construction, though attached to the hull in a different manner, and it is much

shoaler, the total draft being but 14 feet as against 22 feet. The depth of body is a little greater than in *Pilgrim*, making only about 8 feet of fin. The lead bulb is longer and larger, projecting 3 feet beyond the after side of the fin and weighing some 40 tons. Through the fin a centerboard works, increasing the total draft to about 22 feet.

The sail plans of the four are substantially the same in outline and details, and apart from the bronze bottom of *Vigilant* there is little difference in construction, either in hull, rigging or sails; the main points of difference being in dimensions and type, as already described.

This difference is so great, and the accompanying effect on the future of yacht designing must be so powerful, that a thorough test of each yacht is in every way desirable; but the indications now are that the trial races will afford only a partial and inconclusive test as a basis for next year's work.

Space forbids a detailed account of the trial races which resulted in the choice of the *Vigilant* as the Cup defender.

Continuing the quotation from Mr. Stephens:

Compared with previous races, it must be admitted that the technical issues and the possible results of the coming contest are of little importance. The great point of keel *vs.* centerboard has been practically decided since the last Cup races in 1887, and is likely to be little affected by the present races. *Minerva*, *Gloriana* and *Wasp* have given conclusive proof that it is possible to design a keel yacht which, to state it moderately, is at least as good to windward as any centerboard boat ever built. The ability in racing, and the advantages and disadvantages of the keel boat in the middle and smaller classes, have been fully demonstrated, and boats of even excessive draught are in general use.

While the problem is somewhat different in the larger classes, there is every reason for the belief that if the question of convenient draught be disregarded, the 85-feet keel can be made quite the equal of the compromise model of the same length. While this fact is gratifying to those who have maintained for so long the keel side of the controversy, it amounts to little in practice, as a yacht of over 12-feet draught can be of little use anywhere save for international racing. Once the limit of 12 to 13 feet is passed, and it is exceeded even in the centerboard Cup defender, the yacht becomes a special machine and of no general use. No yachtsman would deliberate long over the real merits of such a

craft as *Lasca* or *Volunteer*, drawing little over 10 feet, and *Vigilant* drawing 14 feet or over. The success of a large keel yacht, like *Colonia* or *Valkyrie*, can only prove what many have long since accepted and others cannot successfully disprove; it certainly would not lead to the general adoption of the type by American yachtsmen. The success of *Vigilant* is likely to have as little effect; it cannot overthrow the conclusions based on *Gloriana* and *Wasp*, nor will it develop in general use a much deeper or wider type of centerboard than is now found in the larger classes. Exciting as the present contest is, its technical issues are of comparatively small importance.

The course of designing during the previous races for the Cup in 1885–6 and 7 was a very rapid one compared with previous years, but, looking back over the three years since *Gloriana* first appeared, the work of Mr. Burgess and Gen. Paine seems but a slow and gradual course of evolution after the first bold step was made in *Puritan*. Great as the advance was from the existing yachts of 1884 through *Puritan* and *Mayflower* to *Volunteer*, compared to the striking features and radical experiments of the last three seasons, it seems but a slow and gradual growth.

The return of Mr. Herreshoff to the field of sailing yachts has been marked by a bold disregard of the traditions and customs of designing that has best shown itself in the carrying to an extreme of several features that heretofore had only been handled carefully and experimentally by other designers. The value of a full and even convex waterline had been demonstrated by others before *Gloriana* was built; but in her Mr. Herreshoff proved that this fullness could be carried to an extreme, not only without disadvantage, but with positive gain. The canoe hull and the fixed fin had been gradually evolved before the advent of *Dilemma*, but it rested for her and her sisters, *Wenonah* and *Wee Win*, to prove the superiority of the extreme fin form in which the lead ballast is concentrated in the bottom of the fin rather than distributed through the whole depth.

Bold and radical as Mr. Herreshoff's experiments have been, the greatest extreme of all is reached in the third of his large yachts, the successful one of his two Cup defenders. While in the first of the three large boats he has been content with a moderate beam of 23 feet, the same as *Volunteer*, and in the second he has taken another foot, in the third boat he has gone to an extreme before reached only in the old type of shoal centerboard sloop, or 26 feet beam on a waterline of 86 feet, or a proportion of $3\frac{1}{3}$ beams. Compared with *Volunteer* and *Priscilla*, with a proportion of nearly $3\frac{3}{4}$, this is a material increase of beam

over the best standards of modern American practice, and the contrast is still greater when the form of the hull is considered.

While not a "fin-keel" in the common acceptance of the new term, *Vigilant*, in common with *Wasp*, *Gloriana* and *Colonia*, approaches so closely to the type that the hull proper may be considered as one distinct member, and the deep keel or fin as another. Looked at in this way, the hull is comparatively wide and shoal, with a high center of buoyancy, and having more in common with the old American type than any successful yacht of the past ten years. On the other hand, this resemblance is largely destroyed by the immense keel or fin, deep and thick, which makes the extreme draft of the yacht something over 14 feet. Seen from abeam, there is not the faintest indication in keel contour or the ends above water of the old sloop; but viewed head on, the extreme beam, high bilge and great hollow of the floors are all suggestive of the old *Shadow*, and the view of the yacht under way, with a crew of sixty to seventy men to windward, a weight of five tons on a wide boat, is even more suggestive of the successful racing which Mr. Iselin did many years ago in the old sandbagger *Mary Emma*.

The following are the dimensions of the *Valkyrie* and the *Vigilant*, as determined by the official measurement:

	Valkyrie. Feet.	*Vigilant.* Feet.
Length, load water line	85 50	86 19
End of main boom to forward side of mast	92 60	99.37
Fore side of mast to jib stay	66.16	73.80
Fore side of mast to jib-topsail stay	66.16	75 90
Fore side of mast to forward point of measurement	66 16	74 85
Fore side of mast to outer end of spinaker boom	72.00	74.62
Deck to upper side of main boom	3.03	3.08
Deck to topsail halliard block	114.86	125.96
Deck to hounds	63 30	69.08
Length of topmast	51.56	56.88
Length of gaff	55 57	54 76
Sail area, square feet	10,042.	11,272.
Square root of sail area	100 21	106.17
Racing length	93.11	96.78
Allowance	1m. 48s.	...

Valkyrie is measured for 6 feet of excess of spinaker boom.

In *Valkyrie*, in spite of much that has been said, there is not the least suggestion of the Herreshoff boats. Not only are the dimensions different, but the whole treatment of the design shows Mr. Watson's individuality; in fact, he has not even copied himself in *Thistle*.

Like the topsides, the bottom is very much like *Queen Mab*, the keel contour being somewhat different. The bow is long

and more of the V-section than in any Herreshoff boats, the waterlines being straighter. The middle body is quite full, with a rather deep bilge and a thick throat to the floors, but the run is very clean and easy.

The general dimensions of the yacht are unquestionably far ahead of any other Cup challenger, she has a good amount of beam, her lead is very low, and from all accounts she carries her canvas in a way that none of the older boats have done.

What is of even more importance is that her draft is apparently enough for good windward work, her lateral plane is ample, and its distribution indicates a good balance; in other words, she is strong in those points in which all previous keel boats of large size have been notably weak. Whether she is relatively as good as the modern keel boats of medium size is yet to be proved, but she is certainly not lacking, as *Colonia*, *Thistle* and the older boats have been, in draft and in distribution of lateral plane.

Her rig is far heavier than *Vigilant's*, but it is tried and tested, and certainly stronger. It is essentially the same as *Thistle*, and not as light as the modern American boats, but there is little danger of it going to pieces.

As to the probable results of the races the general opinion is all on the side of *Vigilant*, and while yachtsmen admire *Valkyrie*, the majority are looking for a decided and easy victory for the American boat as in past years.

In many respects the two are far more evenly matched than ever in the past, and while *Vigilant* is likely to do the best windward work under normal conditions, there are, in our estimation, two adverse factors in the great beam and the large and light rig. The possession of the Cup has in the past been decided by this same ability to windward under normal conditions, smooth or nearly smooth water and a clubtopsail, or at least a topsail breeze, and under the same conditions *Vigilant* is likely to win. Should it come to disturbed water, even short of a really bad sea, while *Valkyrie* has probably beam enough, we believe that *Vigilant* has too much for her best speed; and while *Valkyrie* has a rig that, though heavier, has been tested for three months, the lighter rig of her opponent presents a serious element of risk which must be greatly increased after two or three days of tossing even in a moderate sea.

FIRST RACE—WINDWARD AND LEEWARD.

Saturday, October 7.

An easterly wind and rain on Friday, with the news of a severe and fatal cyclone on the Gulf coast, gave promise of better

racing weather for the second attempt at the first race, but Saturday morning, after a rainy night, broke as imperturbably bright, warm and clear as any picnic party could wish for. The sea was smooth save for the long roll which is always found off the Hook, and even this decreased a few miles off shore. The wind was a mere draft from the west, and in the hot sun and clear sky there was no promise of much better conditions.

When off the Lightship, both boats swung their largest club-topsails, *Valkyrie* having replaced her hollow yard used on Thursday with a solid one. The hollow spar bent just enough to throw a slight curve in the head that was pretty to look at, but the solid spar stood straighter, like the American. The course given from the flagship was E. by S., a dead run, and at 11.15 the preparatory gun was fired.

The conditions of Thursday were repeated, as regards sails and weather, but this time *Valkyrie* got away first, with *Vigilant* close astern, the two crossing almost together. *Vigilant* set her second balloon jibtopsail, but was a little too soon with it, and it was taken aback for a moment. The spinaker, also set in stops, was broken out as she crossed the line, while *Valkyrie* set hers flying, afterward setting a balloon jibtopsail. The roll of the sea, slight as it was, seemed at first to bother *Vigilant* a little, as her sails slatted and lost the wind.

For the first half hour the pair sailed very slowly, not more than four miles an hour, and, as on the previous day, there was little change of position. *Vigilant* steered to the north, inshore of *Valkyrie*. Apart from the steamer *Monmouth*, which had laid just above the line at the start, regardless of the yachts, the fleet gave no trouble, but each boat was provided with various signs, such as "Keep Clear Astern" and "Your Wash is Hurting Us." A fleet of tugs bearing the New York Yacht Club flag and also a white flag was on hand to police the course, as on the first day.

As they moved slowly along various changes of sheets were made on each boat in the effort to coax a little more speed out of the lagging wind, but with no result for a time. Almost at noon, however, the *Vigilant*, now just inside of *Valkyrie*, began to pick up, and with no indications of a better breeze, at once began to close the gap between them. At this time the roll was less than at the start, and *Vigilant* was steady enough, but *Valkyrie* showed a slight tendency to roll and spill the wind. Although not so sudden and rapid as on the first day, the gain of the following boat was as certain, *Vigilant* came up abeam of *Valkyrie*, their masts were in line for a moment, then the higher

mast passed ahead, and soon the big white hull was clear of the smaller black one. The whole manœuver was watched by thousands, but we have not yet heard a satisfactory reason for the sudden difference in speed from no visible cause after half an hour of even sailing. The only explanation lies in a stronger current of air, though the boats were hardly 200 yards apart, aided, perhaps, by a little better trim of the sails.

Whatever the cause, the effect was that *Vigilant* soon turned the tables on *Valkyrie* for Thursday's work, and ran ahead until she had a lead of half a mile. About 12·25 the wind headed enough to bring in both spinakers, while the balloon jib topsails were trimmed a little for reaching. At 12·49 *Valkyrie* set her spinaker and *Vigilant* followed at 12·52, the wind being still very light, though the yachts were moving decidedly faster than for the first three miles or so. Spinakers were carried until 1·23, the wind working to the south all the time.

The boats were now just under the conditions at which, according to theory, *Vigilant* begins to show at her best, smooth water and a steady though very light clubtopsail breeze, and she increased in actual sailing the lead she first made through a fluke until she led *Valkyrie* by a mile. When she luffed around the mark the time stood 1·50·50, or 2 hours 25 minutes 50 seconds, while *Valkyrie* was not timed until 1·58·56, or a difference of 8 minutes 6 seconds. The average speed over the whole 15 miles would thus be for *Vigilant* about 6 miles per hour, but during the first three miles it was much slower, this distance was probably sailed at 4 miles per hour and the remaining 12 miles at an average speed of about 6½ miles. At no time on the way out were the two yachts close together and in the same wind except in the first drifting.

The wind at the turn was about south by west, or abeam, but it drew ahead until the two were laying their courses nicely and heading a safe distance to windward of the line in case of the inshore breeze breaking them off at the finish. The reach in was made with a varying wind, the two yachts, a mile apart, getting it differently. At one time *Valkyrie* had closed the space considerably, but toward the end she fell back and the time finally showed but slight gain on *Vigilant*. When near the line balloon jibtopsails were set and carried to the finish. *Vigilant* was timed at 3·30·47 and *Valkyrie* at 3·38·23.

The steamer *Monmouth* had made herself conspicuous at the start by blanketing the yachts, and as *Valkyrie* came for the finishing line she again loomed up just ahead of the yacht, running on to the line itself in front of the *May*, so that it was im-

possible for the committee to time the yacht as accurately as is desired, while *Valkyrie* was given the wash of one of the biggest steamers of the fleet. An order from the committee to keep off the course brought an impudent reply from the captain, who otherwise disregarded it. Apart from this incident no intentional harm was done to either boat by the attendant vessels.

The official time of the race was:

	Start.	*Finish.*	*Elapsed.*	*Corrected.*
Vigilant, . .	11·25·00	3·30·47	4·05·47	4·05·47
Valkyrie, . .	11·25·00	3·38·23	4·13·23	4·11·35

Vigilant wins by 5 minutes 48 seconds. The average speed home was 9 knots, which is hardly enough to justify the descriptions of the "strong wind" in some of the accounts. As a test the race is hardly more conclusive than on the first day, even admitting that *Vigilant* gained a little in the sailing after the first fluke, the gain would be very small and the two were never under the same conditions. On the only part of the course which was accurately timed, the reach home, *Valkyrie* showed a little better speed than *Vigilant*.

SECOND RACE—TRIANGULAR COURSE.

Monday, October 9.

Monday morning was clear and warm, with a light haze over the water, which cleared before the start, and a light S.W. wind from the Jersey shore.

The two racing yachts were under way in tow from Bay Ridge before 8 o'clock, *Vigilant* towing into the Horseshoe, where her main sail was hoisted, while *Valkyrie* went straight out to the Lightship, setting her sails when well down the Bay. After sending up her largest club topsail, the sail was lowered and the halyards bent on anew, after which it was again sent up. *Vigilant* set her second club topsail, throwing over the big topsail yard to be picked up by the Commander.

A thick haze covered the water at 9 o'clock, but it lifted before 11, and the sun shone from a clear sky. The wind had been increasing all the morning and ranged from 10 to 12 knots at the time of the start. The three strings of course signals set on the *May* read: Southwest by south, east ½ south, and north northwest ½ west, each 10 miles, nautical, the first leg being dead to windward.

With a start to windward, the weather berth was worth working for, and after the first gun fired at 11·15 the pair circled cautiously around, with headsails set and small jibtopsails aloft

in stops. *Vigilant* ran along on port tack above the line, with *Valkyrie* just to leeward, and as she ran ahead *Valkyrie* passed under her stern and out on her weather. *Vigilant* jibed over and *Valkyrie* crossing her bows, went on starboard tack near the Lightship with about 3 minutes to go. As *Valkyrie* ran ahead *Vigilant* swung about on her weather quarter and the two headed for the line together, with *Vigilant* in the coveted weather berth. The times over the line were:

Vigilant, . . 11·25·19 *Valkyrie*, . . 11·25·21

Both broke out baby jibtopsails and the windward work was fairly begun. *Vigilant* was held very high, her headsails shaking and the head of her staysail showing very badly. *Valkyrie* was sailed a little freer and her sails showed full and hard, without a flutter or a wrinkle. From the time she crossed the line she began to foot ahead, all the time holding a good wind. In a few minutes she was clear ahead, and a little later she had opened quite a gap. For twenty minutes this slow but certain gain continued, and then *Vigilant* was eased a little and her staysail began to do better work after a man was sent up the leech in a boatswain's chair to do something to the sail.

At 12·05 *Vigilant* took in her jibtopsail, and a couple of minutes later *Valkyrie* went on port tack, *Vigilant* at once going about with her, being now to leeward but ahead. *Vigilant* could have forced *Valkyrie* about, being on starboard tack, but she made no effort to do so. From this point on *Vigilant's* gain was steady and rapid; she drew clear, and at the same time held better to windward. The sea had an easy roll, and the wind was freshening; the two were heeling to nearly the same angle, each carrying her sail easily; but in spite of lower freeboard, *Valkyrie* showed quite as much side to leeward. Neither was now carrying a jibtopsail, but at 12·42 *Vigilant* again sent up her baby, taking it in at 12·48, when she went on starboard tack, *Valkyrie* having tacked a minute before.

They had now gone about six miles, and the mark was plainly visible under the Jersey shore off Long Branch. *Valkyrie* went on port tack at 12.52, half a mile astern of *Vigilant*, the latter tacking a moment later. At 12·58 *Valkyrie* made a short leg on starboard tack, only holding it for three minutes, and then she stood on in *Vigilant's* wake for the first mark, around which the steamers and tugs to the number of at least 50 were lying. *Vigilant* made her last tack at 1·04·30, jibing around the mark at 1·06·35. The large jibtopsail was set in a couple of minutes, and then the balloon foresail.

Volkyrie made her last tack about a minute before she rounded the mark, her time being 1·11·20. In the beat of ten miles, with a wind increasing from 10 to 12 miles per hour at the start up to 15 at the turn, *Vigilant* had beaten *Valkyrie* just 4 minutes and 35 seconds.

It was now a reach before a strengthening breeze and a little lop of sea on the weather beam. The steamers kept further from the yachts than on the previous days, and there were fewer of them; while no intentional harm was done, the following boat probably suffered some from the wash on each side. *Valkyrie* was for once slow with her sails, the jibtopsail was sent partly up the stay and hung there for some time, being broken out six minutes after she had turned; two minutes later the balloon foresail was sheeted home.

Vigilant took in her jib topsail at 1·26, but set it again at 1·45, sending it up flying. When near the mark, at 1·53, she lowered the sail again, jibing round at 1·59·55. *Valkyrie* was now a long way astern and losing steadily, taking in her jib topsail at 2.02, and jibing around at 2·05·52, or 8 minutes 57 seconds after *Vigilant*, the latter having gained 4 minutes 12 seconds in the reach. The wind had now got up to about 20 miles per hour and was still increasing, blowing about 25 miles on the last half of the third leg. *Vigilant* set her baby jib topsail at the turn, but took it in at 2·16 and shifted to balloon foresail. The wind had been drawing to the westward for some time, and on this leg was about S.W. by W. *Valkyrie* set her jib topsail at 2·09 and carried it for over half an hour, until well up with the finish. Over the last five miles *Vigilant* was heeled well down and the wind was more puffy; her jib was shaking at the head, but the other sails were sitting well and she was traveling very fast. On she came, crossing the line at 2·50·01, and leading *Valkyrie* by 12 minutes 23 seconds elapsed time, having gained 3 minutes 26 seconds on the last ten-mile leg. *Valkyrie* finished at 3·02·24, making the official times:

	Start.	*Finish.*	*Elapsed.*	*Corrected.*
Vigilant,	11·25·00	2·50·01	3·25·01	3·25·01
Valkyrie,	11·25·00	3·02·24	3·37·24	3·35·36
			1st Mark.	*2d Mark.*
Vigilant,			1·06·35	1·56·55
Valkyrie,			1·11·20	2·05.52

VIGILANT'S GAIN.

First leg,	4·45
Second leg,	4·12
Third leg,	3·26

The elapsed times of *Vigilant* were:

	Time.	*Average speed.*
First leg to windward, ...	1'41'35	6. knots.
Second leg free reach, ...	50'20	12. knots.
Third leg reach, ...	53'06	11.3 knots.
Whole course, ...	3'25'01	8.7 knots.

After the race it was announced that *Vigilant* had sprung her bowsprit, though the extent of the injury and when it occurred was not given out. Lord Dunraven, Messrs. Watson and Ratsey and Captain Cranfield conceded very freely the merit of *Vigilant's* performance and her great speed, the only complaint made being againt the wash and interference of some of the tugs and steamers with the second boat.

THIRD RACE—WINDWARD AND LEEWARD.

Friday, October 13.

That Lord Dunraven made a mistake in sending *Valkyrie* over so late in the season is now generally admitted, the result being that she had no time for trial sailing after being refitted, but went into the racing at once. It is hardly likely that she was enough off her proper trim and form to have affected the final result in any of the four days' sailing, but, not unnaturally, her owner and friends ascribed her poor performance alongside of *Vigilant* to the alterations designedly or accidentally made in her ballasting and fore-and-aft trim. She had been lightened considerably by the removal of interior fittings and ballast for the lighter wind looked for on this side, and it is also stated that she was trimmed more by the head than in her home races.

So far as stability goes, she carried her sail well enough in all the races, being apparently under-rigged, and she could have suffered little from the change in this respect. At the same time it is quite likely she handled differently in her lighter trim, and her crew had not had time to understand her and get the best out of her. The same thing is very often seen on the New York Yacht Club's cruises, a yacht winning easily in her class in the cruising runs and being beaten when completely stripped for the Goelet Cup race. Whether rightly or wrongly, Lord Dunraven concluded that the yacht would be better for more weight and a little more trimming by the stern, and on Thursday two tons of lead, loaned by Com. Sutton from the schooner *Loyal*, were taken aboard and stowed as low as possible.

This change of water line and trim of course necessitated a remeasurement, and in the afternoon the yacht was towed to the Erie Basin, where her water line was measured by Mr. Hyslop,

the new figures being 85.92 feet, or a lengthening of just 5 inches, making her sailing length 93.57 feet, and reducing the time allowance from 1 minute 48 seconds to 1 minute 33 seconds.

Thursday night brought news of another severe cyclone in the South and of a storm on its way up the coast, the predictions being cloudy weather and southeasterly breezes of 12 to 20 miles velocity during the day, increasing at night, with rain.

Friday was warm but overcast and cloudy, the wind in the morning being N.E. and shifting to S.E., blowing moderately off the lightship, an oyster sloop being out at the line under full mainsail and jib and carrying them easily. There was more sea than in any previous race, the conditions being similar to the final trial race in September, though with less wind at the start.

Vigilant was under way early off the line, with one reef in and a jib-headed topsail set, and her large jib. *Valkyrie* came out in tow, but when below the Narrows her mainsail was lowered, and one of the throat halliard blocks brought down on deck for some repairs to the shell. The block was fitted up and replaced, and the mainsail set, but it was 11·15 before *Valkyrie* neared the Lightship, with a small reef in the mainsail and a jibheader set over it, and her headsails in stops.

As she cast off her tow line at 11·20 the course signals, due East, were set on the *May*, but by this time *Vigilant* was hove to, and the "wig-wag" flags were at work on board, signalling to the *May* that she needed time to make repairs. The signal C. G., "Race postponed on account of fog," was set on the flagship, though the horizon was clear and the sun was trying to look through the clouds; but no other signal for a postponement had been arranged.

Vigilant lowered her staysail and ran off to the eastward, her crew being busy with the centerboard. The board had jammed, and in trying to raise it the cogs in the winch had been broken. The board was finally lowered about 11 feet, and carried this way on the wind. Off the wind it was raised by a tackle until but 5 feet projected. When *Vigilant* stood back, about 11·45, one of the club tugs spoke her and ran up to the *May*, and at 12·07 the blue peter went up, signifying a start.

The two were now under the same canvas, each with jibheader set over a single-reefed mainsail, and jib and staysail. The wind was moderate, the schooner *Yampa* being out under lower sails and maintopsail, and the sea was easy.

The course was dead to windward, and the two ran off southwest of the Lightship just before the preparatory gun fired at

12·17. With the gun there begun some of the prettiest work seen in a very long time as the great vessels chased each other like a pair of kittens in the effort to get the weather berth on the line. *Vigilant* was standing away on port tack when the gun fired, and *Valkyrie*, just by the Lightship, ran down toward her. After a little manœuvering, at 12·20, with 7 miles to go, *Vigilant* hauled her staysail to windward and ran toward the Lightship, with *Valkyrie* turning and following her. *Valkyrie* crossed *Vigilant's* wake and went to windward, with 3 miles to go, but as she forged ahead *Vigilant* slipped in astern, and between her and the mark, getting to windward. *Valkyrie* came round like a bicycle, jibed over, and slipped in alongside the Lightship and to windward, with less than a minute to go; but *Vigilant*, further ahead, was obliged to reach along the line, going so fast that when the gun fired she was almost aboard the *May*, and barely shaved over the line by a sharp luff. *Valkyrie* cut the weather end of the line at 12·27·10, while *Vigilant* crossed the lee end, with headsails shaking, just 3 seconds later.

As it proved, the first tack was a long one, at least six miles inshore from the Lightship toward the Long Beach Hotel, on the Long Island shore, *Valkyrie* pointing for the big hotel when half way out. The sea was abeam and the two yachts were pitching some. Of the two, *Valkyrie* was carrying her sail decidedly the better, in a way that suggested that the half reef in the mainsail was hardly necessary, or that she might even have done as well without the extra ballast. At no time in the races has she shown any tenderness, and to-day, in the strongest breeze, she was notably stiff. She pointed fully as high as *Vigilant*, and what is much more, she had none of the appearance of sliding off, but seemed to hold her windward berth easily and comfortably, both footing and pointing as she did so.

Vigilant had all the sail that she wanted, if not a little more, and heeled to a greater angle than *Valkyrie*, though in doing so she does not bury her lee side or show much less of it; the effect seems to be to roll out the weather side when pressed, rather than to bury to leeward. She was well sailed, but in open boat fashion, luffing out all the time, and though she footed quite as fast or a little faster at times, she was doing no better windward work with a centerboard than *Valkyrie* with a keel. From her performance in the trial races one would naturally look to see her sidle up to windward in her peculiar way, but this time she seemed to hold on hardly as well as the keel boat. Her jib seemed large and may have hurt her some, but her performance altogether was inferior to the keel boat.

At 12·50 *Vigilant* had not improved her weather position, but was footing faster than *Valkyrie* and had gone clear ahead. Captain Cranfield had devoted all his skill to blanketing his rival, but by her footing *Vigilant* had finally gone clear ahead and got the wind unbroken, but at the expense of a weather position.

At 1·12 she tried a tack off shore, evidently expecting to weather *Valkyrie*, but in this she was very much out; after standing on for two minutes and a half she had to go back to starboard tack in a worse position than before, well under *Valkyrie's* lee. So much had she lost that she could now afford to tack across *Valkyrie's* wake, but as she came up in the wind at 1·18·30 *Valkyrie* swung around and was at once under way on her weather bow. To add to *Vigilant's* loss, a jib sheet was adrift for a short time.

The wind was now stronger than at the start, and the sun showing through a fairly clear sky, the promised cyclone not having materialized as yet. The yachts were now heading into the seas and, the result was visible on the wide boat, as she lost more than in the first hour with the seas abeam. This tack, too, was a long one, lasting nearly an hour. When they came about near the outer mark at 2·15 *Valkyrie* had a lead of three-eighths of a mile.

She luffed around the mark at 2·33·40, and her boom swung over to starboard, a big white spinaker going up just as *Vigilant* rounded at 2·35·35. In the beat of fifteen miles *Valkyrie* had gained just 1 minute 55 seconds on *Vigilant*.

The wind had been increasing, and there was too much of it to set a spinaker flying; but *Valkyrie's* crew are used to no other way, and up it went, quickly and in good shape, but with sheet and tack far off, the big sail way up in the air. *Vigilant* was just five minutes in running out her spinaker boom from its position on deck, mastheading the sail in stops and breaking it out; but, like *Valkyrie*, she kept the sheet and tack well off, and the sail mounted skyward like a balloon.

At 2·47 the largest jibtopsail went up flying on *Valkyrie's* stay, the same sail she has set off the wind in the previous races. *Vigilant* was in trouble with her jibtopsail, and a man was sent down the topmast stay before the jibtopsail could be sent up in stops. In hoisting the sail the spinaker fouled one of the hanks, and had to be cleared before the jibtopsail could be fully hoisted. When it was finally broken out at 2·50, however, it proved to be a ballooner and not a working sail. Meanwhile her big crew had not been idle while one man worked aloft, but though the

boom was squared the reef was shaken out at 2·55 and the working topsail hoisted higher to the topmast head. In shaking out the reef, a man was hung from the masthead in the bight of a gantline, and hauled along the boom by an outhaul casting off the stops. At the same time *Valkyrie* set a balloon foresail and mastheaded her working topsail, but made no attempt to shake out the reef, though she was losing steadily to *Vigilant*.

For over a quarter of an hour a man was visible at the topmast head of *Vigilant* and another at the gaff end, lashing the head and tack of the topsail and casting off the halyard and sheet, and when this was done the second club topsail was sent up over the working topsail, which was left in place.

Vigilant had all this time been gaining steadily, and at 3·30, just before the clubtopsail went up, she ran through *Valkyrie's* weather and the white spinaker of the latter, which had been torn a little in setting, split clear across. Almost on the moment the sail was taken in and the light linen one set, but this, too, split before it was sheeted out, going in two pieces from head to foot. The first spinaker was of strong and heavy Scotch linen. In setting it, the foot was torn on the bitts in two places. Later on the sail went over the topmast stay and caught in a hank, making a tear which spread clear across just as *Vigilant* ceased to blanket *Valkyrie*.

Valkyrie's chance was now gone, with the finish but three miles away, and *Vigilant*, in spite of the rising wind, carrying spinaker, baloon jibtopsail and clubtopsail, twice the area of canvas. Her crew worked on in spite of such discouragement, and at 3·38 set up a large jibtopsail as a spinaker, but it was too late, a dozen minutes more and *Vigilant* was over the line, winning the race by only 40 seconds corrected time, the official times being:

	Start.	*Finish.*	*Elapsed.*	*Corrected.*
Vigilant, . .	12·27·00	3·51·39	3·24·39	3·24·39
Valkyrie, . .	12·27·00	3·53·52	3·26·52	3·25·19

On the windward work *Valkyrie* led by 1 minute 55 seconds, and off the wind *Vigilant* gained 4 minutes 8 seconds.

The wind at the finish was much stronger than at the start, but it is hardly necessary to state that yachts do not carry balloon jibtopsails, large spinakers and clubtopsails in a living gale or a cyclone, and that the reports of the wind and sea are mostly exaggerated; at no time during the day did the accompanying steamers roll badly or become uncomfortable, and one could walk about the upper decks without serious trouble from the wind.

Valkyrie's defeat may be ascribed to the loss of her two sails, as she would probably have saved her time by a small number of seconds had the first spinaker held, and might even have won had the second one not got under her bow after splitting. *Vigilant's* victory, however, is by no means laid to this account alone, but to the bold and skillful way in which the kites were piled on to her all the way home. With a strong following wind, increasing all the time, she spread all of her kites and ran the risk of losing her topmast and being badly beaten, rather than that of *Valkyrie* saving her time by a small margin. The work in shaking out the reef and reeving sheet and halliard, and setting the clubtopsail, was very creditably done and won her the race.

Taken altogether, the race was an exceptionally fine one, and the honors are very even. Many have expressed their astonishment at the good showing of *Valkyrie* compared with her previous work on the wind; but there is really nothing contradictory about it. Mr. Watson has turned out a boat that is far and away superior to any keel yacht of large size ever floated, a boat that would probably have done well alongside of anything built to meet her of the *Volunteer* type improved up to date. She is not only fast through the water, but she carries a large rig with ease, and holds to windward in the same way that the smaller keel boats do. Her ocean voyage bears testimony to her strength and sea-going qualities, and in the detail of quick working she is ahead of anything on this side of the water. From a scientific point of view, the perfection of her model is shown in her speed in very light weather and her quick working under all conditions.

At the same time it is quite evident that in a topsail breeze, light or heavy, she is outclassed and overpowered by *Vigilant*. The third and last of the three large Herreshoff boats of the year is very evidently intended to make the most out of the New York Yacht Club's rule and the prevailing conditions of American racing, when a clubtopsail is the rule, at least a working topsail being always carried, lower sails being an exception and reefing unknown, the race of Friday being the first in which one of the large single-stickers, from *Puritan* to *Vigilant*, has reefed her mainsail, and even then she carried a working topsail over it.

With the power due to great beam and draught, carrying 1,200 feet more sail than her opponent, and with a great hollow in her floors, *Vigilant* stands as the latest representative of a type that has long been recognized as very fast in moderate weather.

Compared either with *Volunteer* or *Valkyrie*, she is much nearer to a racing machine, and her influence on designing is likely to be for the worse rather than the better, but, at the same time, in producing her Mr. Herreshoff has clearly worked within the literal limits laid down by the clubs, and his latest boat is but the logical production of the present rule which we predicted several years since during the battle of the 40-footers.

On a limited length he has built the most powerful yacht yet seen in the larger classes, paying for his large sail plan the price set by the rule; and with no limit to the number of crew, he has used to the fullest extent the privilege accorded by the rule in designing a yacht which, in spite of her size, could profit materially by the use of movable weight to windward. While the tendency of this advance may be deprecated, it must be admitted that the fault lies with the clubs which have made and retained the rules, rather than with the designer who has produced an extreme boat under them, and until the clubs, American and British, see fit to define and limit the racing machine as a distinct type from the all-around yacht, it would be absurd to raise any such distinction in the present case.

The conditions of British racing call for a certain type of boat, and *Valkyrie* must be considered a perfect craft for her home racing, as well as a very fast boat on this side. The prevailing conditions of American summer racing call for a very different type, while the rules allow an extreme latitude to the designer. After three years of experiment in the direction of the fin-keel and a very hollow section, Mr. Herreshoff has carried the same principles to an extreme in one of his three large yachts, and it must be said, with complete success. Under all the conditions which she has met in her various races, *Vigilant* has proved very fast, and though these conditions do not include the whole range of yachting weather, they quite cover the average in the 86 foot class.

Opinions differ as to her performance in a strong breeze and rough water, conditions under which she has never been tried, but has only approached in two races, the last trial race and the last Cup race. A great deal of nonsense has been printed about the furious gales and breaking seas on each of these occasions, but neither day approached the proportionate weather for an 86-footer to that in which many of the 40-foot races are sailed.

While *Vigilant* has given every indication of speed and ability in a reefing breeze and a sea, our own opinion is that she reaches her best conditions in smooth water and with first or second club-topsail set; her advantage over *Valkyrie* beginning, for instance,

when the two cease to drift and begin to sail, as in the first part of the triangular race of Monday, and ending in such a strong breeze as blew on the last leg of the same race. Then, in practically smooth water, heeled well down under her second club-topsail, *Vigilant* traveled very fast, and was probably near her best point of sailing. Within this range of conditions she beat *Valkyrie* fairly and very badly, about four minutes on each ten-mile leg, and this in fair sailing and with no flukes.

There is in this performance, however, nothing to justify the popular assumption that she should do as well under the widely-different conditions of Friday, a much stronger wind and more sea; on the contrary, the good performance of *Valkyrie*, with less beam, a fuller section, and even more stability, is quite in accord with theory and practice.

It would be interesting to see more of this same work; nothing finer has been seen here in a long time than the hard, close fight to windward; but at the same time it must be conceded that *Vigilant* is very much faster in ordinary racing weather and over long, straight courses.

It is quite in order that the annual agony over rules and restrictions may be renewed this fall on both sides of the water, and the questions of fin keels and their allied types of racing machines *vs.* all-round yachts, and of a limit of crew in the larger classes, may be discussed with renewed vigor, and the usual failure to reach any definite conclusion *pro* or *con*.

Although such quick working as *Valkyrie* displayed is not called for on this side as in England, it has won the admiration of thousands of yachtsmen who have followed every race, and it is quite probable that this quality will be more highly appreciated than in the past, and greater effort made to obtain it

On Saturday *Vigilant*, in tow of *Commander* and following by the triumphant *Hattie*, left Bay Ridge for New Rochelle, where her crew will be paid off. She will lay up at City Island. *Valkyrie* also will winter at the same place, Lord Dunraven having decided not to attempt the long passage home this fall.

THE ATLANTIC RECORD.

It was not long after they began regular running until the *Campania* and the *Lucania* had beaten all previous records, so that interest became centered on each voyage to see if it would show an improvement on their own records. And almost every trip has shown a lowering of the record up to the last available before this number of the JOURNAL goes to press. It has seemed likely to be most interesting to give an account of the various trips, and the following extracts are from "Engineering."

Although anticipated, because of their great power, the performances of the two Cunard steamers in their last Transatlantic passages are most creditable to the designers and builders, for the one steamer beat all previous records, and the other, in her first run at sea, maintained a speed not approached by any steamer on a maiden voyage. The former, the *Campania*, in the homeward run, accomplished the trip between racing points—Sandy Hook and Daunt's Rock—in 5 days 14 hours 55 minutes, having throughout that time maintained a mean speed of 20.94 knots. While accomplished in less time than her former best run—in May last, when 5 days 17 hours 27 minutes were needed for the sea run—the voyage does not indicate the same high mean rate of speed, for the May run was on the southern and longer route, the mean then being 21.3 knots, the best on any sea run yet made. The performance, however, is satisfactory, and promises still better results; and here it may be interesting to glance at the progress since the former Cunard steamers, the *Umbria* and *Etruria*, held the record before the advent of the *New York* and *Paris*:

HOMEWARD.

	Days.	*Hours.*	*Minutes.*		*Knots.*
1888—*Umbria*, . .	6	3	12	=	19.11
1892—*New York*, . .	5	19	57	=	20.10
1893—*Campania*, . .	5	14	24	=	20.94

It must not be assumed that the *Umbria's* record was not broken until 1892, for not only the *New York*, but the *Paris*, *Ma-*

jestic and *Teutonic* were, in the interval, by successive efforts, bringing it down by minutes. The *New York* passage given shows rather the improvement made jointly by the other steamers between 1888 and 1892, while the *Campania's* run indicates what the Cunard Company have again done towards lessening the time needed for the voyage. The best speed of the *Campania*, 21.3 knots, is over two nautical miles per hour better than that of the *Umbria*, but there is every likelihood of it being more, while the *Lucania* may even eclipse her companion. In her first run to New York she completed the sea voyage in 5 days 14 hours 50 minutes, while her time from Liverpool, including stoppage at Queenstown, was 6 days 4 hours 10 minutes. The daily runs were 460, 490, 498, 516, 523 and 284 miles to complete the run, and the improving tendency promises a record run home next week, as in the case of the *Campania*, since it indicates complete satisfaction on the part of the designer, Mr. Andrew Laing, who was attending the machinery, and who would not have opened out his engines unless everything was favorable.

(*September 29th.*)

The Cunard liner *Lucania*, in the homeward run of her maiden trip to New York, as in the westward run, attained a most satisfactory result. The time taken on the voyage was 5 days 17 hours 21 minutes. This is only second to the fastest voyage of her sister ship, the *Campania*, a fortnight ago, when the time taken was 5 days 14 hours 55 minutes. The *Lucania's* run home is only 6 minutes shorter than the first homeward passage of the *Campania*, which was a record performance. The latter vessel went on the winter course, however, covering a much longer distance than the *Lucania*, so that the mean speed is greater—21.3 knots as compared with 20.4 knots maintained by the *Lucania* in her 2,801 miles' run. But the newer vessel had to slow down her machinery for thirty-one hours, owing to the fog on the Newfoundland coast, and experienced strong northeast winds and head seas for the remainder of the voyage. These facts, which are demonstrated by the increase in the day's run from 415 miles on the third, the foggy day, to 514 miles on the fourth day out, indicate that the vessel might, under normal conditions, have easily broken even the *Campania's* record, and enabled Mr. Laing, the engineering manager of Fairfield, who was on board, to claim the credit of having with both ships beaten the record in maiden voyages. As it is, there is every likelihood of future record breaking. On one of the days of the run—the 20th instant—the distance covered was 514 miles. The day is

not a complete twenty-four hours, as the vessel steams towards the sun, so that the mean of the day's run was over 22 knots. The *Campania*, however, covered 517 miles in one day in her record passage early this month.

The daily runs of the *Lucania* were 480, 485, 415, 514, 473 and 434 knots. As to the important question of vibration, the passengers are reported to have been high in their praise of the steadiness and sea-going qualities of the vessel and the smooth working of the machinery. It is, therefore, evident that the means taken to obviate the vibration which developed in the *Campania* have had some effect. The changes made may be briefly described. In the *Campania* there is a well forward and aft, which separates the promenade deck from the forecastle and the poop. In the *Lucania* this well has been covered in, so that the strong iron-plated promenade deck extends right fore-and-aft, and must help to stiffen the upper structure. In the interior of the vessel girders have been thrown athwartship where convenient, and particularly in the center of the ship, where the boiler compartments are situated. These girders, again, are braced by diagonal stays. 'Tweendecks, too, extra columns or pillars have been introduced, so that the original strength of the vessel has been greatly augmented. That the vessel was originally very strongly built was shown in our narrative of the operations of construction, and experience alone could show, in the case of a vessel of such unusual proportions, how extraordinary conditions could be met satisfactorily.

(*October 13th.*)

The Cunard steamer *Lucania* has succeeded in her second voyage to New York in breaking the record held for a long time by the American Line steamer *Paris*, reducing the time on the voyage by 39 minutes, the time now being 5 days 13 hours 45 minutes. The Cunard Company now have the credit associated with the record for both outward and homeward passages, and it may be interesting here to note the progress made since this credit was due to the *Umbria* and *Etruria's* performances:

OUTWARDS.

	Days.	*Hours.*	*Minutes.*		*Knots.*
1888—*Etruria*, . .	6	1	45	=	19·3
1892—*Paris*, . .	5	14	24	=	20.7
1893—*Lucania*, . .	5	13	45	=	20 75

It will thus be seen that the Inman and White Star steamers by competitive effort reduced the passage between 1888 and 1892 by 11 hours 20 minutes, and now the Cunard steamers have entered upon a course of record-breaking runs, so that the time will yet be reduced considerably by them. The *Lucania* in one day made 560 miles. As she was steaming from the sun, the time from noon to noon was over the 24 hours, and the mean speed works out to 22½ knots. If she is fortunate in having for a whole voyage the favorable weather experienced on that day, the time taken may be easily reduced to 5 days 6 hours.

The improvement on the speed of the *Etruria* is very marked, but it must not be forgotten that the engines fitted at Fairfield by Mr. Laing into the newer vessels are of greater power and efficiency than those he designed for the earlier steamers. The daily runs were 452, 503, 542, 508, 560 and 210 miles, and the cable received indicates that the ship was "very steady," a point of interest in view of inaccurate statements regarding vibration, and one of satisfaction to Mr. Saxton White, as well as to the Fairfield Company. In fact, we understand that the Cunard Company are high in their praise of both ship and engines. We have said that the Cunard Company also hold the homeward record, and it may be indicated that the improvement on the *Umbria* and *Etruria* passages is also marked:

HOMEWARDS.

	Days.	*Hours.*	*Minutes.*		*Knots.*
1888—*Umbria*, . .	6	3	12	=	19.1
1892—*New York*, . .	5	19	57	=	20.10
1893—*Campania*, . .	5	14	24	=	20.94

The *Campania* on a winter run, however, maintained for the whole voyage 21.3 knots, and here again one finds encouragement in the hope that before long the duration of voyage may yet be reduced to 5½ days, for, as a rule, vessels steam better after their first year's service.

(*October 27th.*)

The two new Cunard steamers *Campania* and *Lucania* continue to demonstrate their good qualities, and the latter has just completed a round voyage in which she broke the record both out and home. Moreover, while she was excelling all previous performances, the *Campania* was making the trip out in less time, so that in one week both records were broken. In other

words, while the *Campania* was breaking the *Lucania's* record outwards, the *Lucania* was retaliating by breaking her consort's best performance homewards. Taking, first, the round voyage of the *Lucania*, she covered, running between Queenstown and Sandy Hook and back, a distance of 5,580 nautical miles, the time taken being only 11 days 7 hours 15 minutes, while fifty years ago it was considered marvellous if this distance was traversed in 28 or 30 days. The speed was very uniform throughout, the mean outwards being 20.75 knots, and homewards 21.01 knots. On the outward run the highest speed for a day was 22½ knots, the unprecedented distance of 560 nautical miles being covered, while on the homeward run the longest distance traveled between noon and noon was 500 knots, which works out to about 21¾ knots, as the vessel was steaming towards the sun. The log shows the mileage at noon on each day as follows: 28, 480, 469, 490, 500, 490 and 348 to Daunt's Rock. The total is, therefore, 2,805 miles, and this distance was covered in 5 days 13 hours 30 minutes, the mean speed being 21.01 knots. This time is 1 hour 25 minutes better than the two record passages of the *Campania*. The two Cunard steamers have, therefore, improved upon the homeward performance of all other steamers to the extent of about 6½ hours, while since the *Umbria* held the record in 1888 the improvement has been 13¾ hours. But still better results may be looked for. The value of the fast run home is demonstrated by the fact that the passengers landed at Liverpool on Friday afternoon in time to get to London and Glasgow the same evening, so that the voyage from New York to those cities was made well within 6½ days.

The *Campania's* run last week to the West marks an equally satisfactory reduction in the time occupied in the voyage. Her time was 22 minutes less than the *Lucania's* performance, the distance of 2,786 nautical miles being covered in 5 days 13 hours 23 minutes, so that the mean speed was 20.88 knots. It is most remarkable that the time taken on the outward voyage should be within seven minutes of the duration of the homeward voyage. The running of the *Campania* was most uniform, the distances recorded at noon of each day being 456, 517, 524, 523, 533 and 233 miles to Sandy Hook. The engineers of both ships speak highly of the satisfactory working of the machinery, and they confidently predict better voyages soon. Both vessels leave at the end of this week again, the one from New York and the other from Liverpool, and as there is a healthy rivalry between the staffs on each ship, we may again have double retaliation.

(*November 10th.*)

The two new Cunard steamers *Campania* and *Lucania* have been breaking each other's records again, the one homewards and the other to the west. The *Campania* in her voyage homewards last week maintained throughout the whole voyage a mean speed of 21.28 knots, but on the fourth day out she averaged about 21¾ knots. The time taken on the voyage of 2,812 nautical miles was 5 days 12 hours 7 minutes, an improvement of 2¾ hours on her previous run a month ago, and nearly 1½ hours better than the record of the *Lucania* a fortnight ago. The runs to noon of each day were 47, 491, 490, 491, 505, 495 and 293 miles. This is the second round voyage on which records have been reduced both ways, the *Lucania* having a fortnight ago, completed a splendid performance; but now the *Campania* has covered the double voyage in 11 days 1 hour 30 minutes net steaming time, as against 11 days 3 hours 15 minutes, the best round voyage of the *Lucania.* Twenty five or thirty years ago this would have been regarded as a good record for half the voyage. The *Lucania* in her outward trip was at the same time excelling the *Campania's* previous westward run, finishing the trip in 5 days 12 hours 47 minutes, during which she covered 2,780 nautical miles, the daily runs having been 481, 542, 536, 490, 535 and 196 miles to Sandy Hook. The mean speed is, therefore, 20.93 knots. The passage is 58 minutes better than the *Lucania's* run a month ago, and 36 minutes better than the *Campania's* time a fortnight ago.

NOTES.

COMPARISON OF THE THOMPSON, TABOR AND CROSBY INDICATORS AT ABOUT 800 REVOLUTIONS.—BY EDWARD J. WILLIS.

The object of a test conducted by the writer was to ascertain if there were any radical differences in the records of these instruments at moderately high speeds. The instruments used were not specially provided by the manufacturers, but were those usually supplied to the public. They were carefully examined before the test and found to be in good order. The engine selected for the test was an 8 by 12 Ball engine running an Edison dynamo. In order to obtain symmetry of position, four instruments were used, one Thompson, one Tabor, and two Crosby indicators. These were connected with the head end of the above-mentioned engine, care being taken to give each instrument the same size, length and form of pipe. By this construction each indicator had about 9 inches of $\frac{1}{2}$-inch pipe and two elbows between it and the cylinder. An iron brumbo pulley carried a hard-drawn wire which was stretched tight by four spiral springs. To this wire the four drums were connected by four short cords of equal length cut from the same hank and making the same number of turns. The springs of the drums were adjusted to as nearly the same tension as was possible. A special apparatus was made for the simultaneous application and release of all four pencils. The results are given in table on following page.

All the cards taken are given above, and none were cast aside to make results more consistent. In appearance they looked very much as if they were taken with the same instrument. It is to be noted that only once did the apparatus for pencil application fail to work neatly. The variation in horse power as given by the different indicators is, in the opinion of the writer, easily accounted for by the various unavoidable errors likely, even when using duplicate instruments, such as planimeter inaccura-

Set Number.	Indicator.	Boiler Gauge.	Revolutions.	Spring.	Mean Effective Pressure.	Horse-Power.	Remarks—Cards.
1.	Thompson	80	293	80	22.11	9.9	Good.
	Tabor	80	293	80	21.56	9.7	"
	Crosby No. 5	80	293	80	21.88	9 8	"
	Crosby No. 7	80	293	80	21.69	9 7	"
2.	Thompson	90	295	80	25 24	11.3	Good.
	Tabor	90	295	80	25.24	11.3	"
	Crosby No. 5	90	295	80	24.98	11.2	"
	Crosby No. 7	90	295	80	24.81	11.1	"
3.	Thompson	75	295	50	17.24	7.7	Good.
	Tabor	75	295	60	17.61	7.9	"
	Crosby No. 5	75	295	60	18.33	8.2	Double & bad.
	Crosby No. 7	75	295	60	18.43	8.3	Good.
4.	Thompson	75	295	50	22.84	10.3	Good.
	Tabor	75	295	60	21.63	9 8	"
	Crosby No. 5	75	295	60	22.28	10.0	"
	Crosby No. 7	75	295	60	23 25	10.6	"

cies and slight differences in the lubrication of the indicator pistons. After the test each set of springs was tested simultaneously by steam against a mercury column. The column is of careful construction, and temperature and other corrections were properly applied. The spring errors thus found did not, in any instance, exceed 3 per cent., and the results given above have been so corrected. The writer usually finds springs slightly soft. This is probably due to the fact that the makers prefer an error of 1 or 2 per cent. in favor of rather than against the horse power of an engine. It would appear from these experiments that, if care were taken to see that the drum motion were as it should be, the relative advantages and disadvantages of these instruments would be mainly ones of facility rather than of accuracy.—"American Machinist" of August 31, 1893.

FAILURE OF METAL STRUCTURES FROM FATIGUE.

In the annual report for 1892 of Mr. Michael Longridge, C.E., to the insurance company of which he is chief engineer, perhaps

the most interesting part is that which deals with several cases of failure by fatigue which have occurred during the year. Mr. Longridge, in commenting on these, points out that the prevalent idea amongst the users of machinery, that because a rod or shaft has borne a certain load without breaking, it will continue to carry that load indefinitely, is fallacious. This has long been known to locomotive engineers, who remove their driving axles after a certain mileage, quite irrespective of visible signs of failure. The low stresses at which failure took place in the cases recorded by Mr. Longridge are, however, noteworthy, the figures being nearly always notably below what might have been expected from Wöhler's experiments. The single exception appears to be that of an engine beam of cast iron, as we take it to be, though the nature of the material is not directly stated. In this instance the failure took place by the top and bottom flanges of the beam cracking across as the engine was doing its ordinary work. From 1872 to 1880 the stress on the flanges of this beam was alternately $\pm$ 2.5 tons, and was repeated about 41½ million times. Since 1880 the stress was $\pm$ 2.1 tons, repeated alternately in either direction 62½ million times. It will thus be seen that the range of stress was 5 tons during the first period and 4.2 tons during the second. Wöhler found that specimens of cast iron from a locomotive cylinder tested by him failed after from 35,000 to 78,000 repetitions of stress, ranging from 0 to slightly over 5 tons, whilst specimens stressed from 0 to 4.78 were unbroken at 7,000,000 repetitions. From this it would appear that the metal used in the beam must have been of better quality than that experimented on by Wöhler.

All the other cases refer to shafts. Thus, a shaft of Bessemer steel broke after making 81,600,000 revolutions under a stress of 11,000 pounds. Another shaft of wrought iron broke after 102,000,000 revolutions under a stress of 7,800 pounds to 9,700 pounds per square inch, whilst a third shaft, also of wrought iron, broke after 123,500,000 revolutions under a stress of 8,500 pounds. Wöhler's experiments on repetition of stress would lead one to expect that these stresses should be carried indefinitely. It should, however, be noted that in Wöhler's experi-

ments the stresses were direct thrusts or pulls, whilst the shearing stresses due to torsion on the above shafts must have been very important, and the conditions are, therefore, by no means identical in the two cases. Some elasticians hold that a material always fails by shear, even when it nominally gives way by direct tension or compression, and there is much to support this view. If this be so, the loads obtained by Wöhler as those which should be borne indefinitely by an iron bar subject to alternate tension and compression, correspond to shears of just half the value of the normal tensions and compressions. Thus, according to Wöhler, a wrought-iron bar should carry indefinitely repetitions of loads ranging from 7.6 tons tension to 7.6 tons compression. The corresponding shears are then ± 3.8 tons, *i. e.*, about ± 8,500 pounds. This appears to be greater than the range of shearing stress in Mr. Longridge's shafts, and apparently only a portion of the discrepancy can thus be accounted for.—"Engineering."

NICKEL-STEEL ARMOR TRIALS AT CREUSÔT.

A specimen of some nickel-steel armor plates which have been manufactured at Le Creusôt for the new Russian Black Sea battleship Tri Sviatitelia (Three Saints) has been tried at Le Creusôt in the presence of the members of the Russian Naval Commission, and has given some remarkable results. The plate measured 8 feet by 8 feet, and was 15.9 inches thick. The conditions of acceptance were that it should receive four blows from Holtzer projectiles of chrome steel, weighing 317 pounds apiece, and fired from a 9.4-inch gun with a striking velocity of 1,945 foot-seconds; and it was stipulated that no piece of the target should be broken off, and that in no case should the base of the projectile penetrate the target to a depth of as much as 7.8 inches. The four rounds were fired at the angles of a square which was painted on the center of the target, and which measured 4 feet each way. The order of the shots was (*a*) right lower corner, (*b*) left lower corner, (*c*) left upper corner, (*d*) right upper corner, and the following, according to the *Times*, were

the striking velocities and injuries to projectile and plate: (*a*) Velocity, 2,001 feet per second; penetration of the point of the projectile, 14.1 inches. The projectile flew backwards with the point smashed and the shoulder somewhat set up. The target showed three very fine cracks running from the wound. (*b*) Velocity, 1,948 feet per second; penetration of the point of the projectile, 10.9 inches. The projectile flew backwards, broken into numerous fragments. As before, three fine cracks developed in the target. (*c*) Velocity, 1,923 feet per second; penetration of the point of the projectile, 14 inches. The projectile flew back with the head smashed and the cylindrical part somewhat set up. A single fine crack was remarked. (*d*) Velocity, 1,962 feet per second; penetration of the point of the projectile, 9.9 inches. The projectile flew backwards, broken into numerous fragments. There were no fresh cracks, and the old ones were not increased. Examination of the back of the target revealed the existence of low swellings, varying from 1 inch to 1.7 inches in elevation, behind each point of impact. Behind points (*a*) and (*b*) there were some fine cracks; behind points (*c*) and (*d*) there were no cracks at all.

LONGEVITY AND SERVICE OF MODERN STEAMERS.

The despatch of modern steamers is quite in keeping with their speed. It is not so many years ago that a fleet of five vessels had to be maintained at sea to enable a weekly service between Europe and America to be kept up, and this excluding a reserve ship. When the White Star people began to get their boats round in four weeks the wiseacres said that they were cutting into the necessary time in port and that they would pay for their expedition in breakdowns. Now, every line gets its ships round in four weeks, and when the American line began to make a fleet of three ships do the work no one took much notice. Yet the *Paris* and *New York* have been successfully running since July with three days only in port at each end of the voyage, and the *Chester* is to be held in reserve. One of the consequences of this expedition, of course, is that vessels are

making more voyages in the course of a lifetime than heretofore. · It was not until a quarter of a century had passed over the Atlantic Ferry that a vessel succeeded in surviving to accomplish her hundredth round trip. Now we think nothing of that. The *Etruria*, one of the fastest greyhounds afloat to-day, will start on her hundredth trip in October, and the Guion liners, *Wyoming* and *Wisconsin*, whose requiem has just been sung, had both accomplished over two hundred double trips, or say, a million and a quarter nautical miles in the twenty-three years of their career.—" Marine Engineer."

STEEL *VS.* IRON TUBES.

An important discussion took place before the Railway Master Mechanics' Association at its recent Saratoga meeting on the character or merits of steel and iron tubes, respectively. It was announced, in a report on this subject, that in the case of a large number of steel tubes, the results, so far as wear is concerned, have been unfavorable. The following definite experiment was cited: An engine was equipped with 114 iron tubes and 113 steel tubes, December 20, 1890. The iron tubes were placed on one side of the center and the steel tubes on the other side of the center of the boiler, the tubes being divided by a vertical line through the center of the flue sheet. At the expiration of fifteen months the flues were all removed, the condition of the tubes being such that seventeen of the iron ones were condemned on account of pitting and corrosion, while sixty-four of the steel tubes were condemned for the same defect, the inferiority of the latter being thus largely in excess of the iron tubes.

PETROLEUM BRIQUETTES.

Briquettes made of solidified petroleum on the system of Lieut. Maestracci, of the Italian Navy, have been tried on several tugboats at Marseilles, and they have been found to give out three times the heat of ordinary coal briquettes, while leaving no residuum behind.

ALUMINUM BOAT.

A boat constructed of aluminum and intended for the forthcoming expedition of Commander Monteil into Central Africa, has just been launched from the Quay d'Orsay, in Paris. It is a flat-bottomed ferryboat, capable of carrying a load of 15 tons, is 33 feet long and 8½ feet wide, and the total weight of the boat is 20½ cwt., of which 18 cwt. is of metal and the remainder of wood. This lightness of construction has only been obtained by the use of aluminum, and the difficulty had to be overcome of rolling sheets of this metal 4 feet long, 2 feet 4 inches in width and 0.12-inch thick. The boat is made in twenty-four parts, each of which can be carried by one man, and which are adjusted by means of bolts, india rubber being provided at the joints of the sections so as to render the boat water tight. With two exceptions, all the parts are interchangeable, and the boat, which is fitted with the tools necessary for assembling it, can be put together in a very short time.

FRENCH BOILERS FOR A BRITISH VESSEL.

The Lords of the Admiralty have placed an order with a French firm, MM. Delaunay, Belleville & Co., for a battery of boilers of the Belleville type for the torpedo-destroyer *Sharpshooter*, of 4,000 horse power, now in course of construction.

SHIPS.

UNITED STATES.

Philadelphia.—The following data of the *Philadelphia's* performance on the voyage from Callao, Peru, to Honolulu are interesting, as showing what our vessels can do in long distance steaming:

Date.	Position at noon.				Distance. knots.	Coal. For steaming, galley, distilling, and all other purposes—tons.
	Latitude.		Longitude.			
	Deg.	Min.	Deg.	Min.		
Aug. 26, 1893.....	Left Callao, Peru ...6·15 P. M.				.....	...
Aug. 27, "	10	13 S	79	46 W	188	30
Aug. 28, "	8	24 S	84	17 W	288	38
Aug. 29, "	6	39 S	88	39 W	280	39
Aug. 30, "	4	53 S	92	54 W	275	37
Aug. 31, "	3	05 S	97	26 W	292	38
Sept. 1, "	1	19 S	101	56 W	289	38
Sept. 2, "	0	16 N	106	42 W	301	38
Sept. 3, "	2	02 N	111	52 W	330	38
Sept. 4, "	3	52 N	116	50 W	320	38
Sept. 5, "	5	43 N	121	13 W	285	38
Sept. 6, "	7	57 N	124	55 W	258	37
Sept. 7, "	9	46 N	128	38 W	246	38
Sept. 8, "	11	39 N	132	59 W	282	37
Sept. 9, "	13	35 N	137	25 W	284	38
Sept. 10, "	15	31 N	142	00 W	291	38
Sept. 11,* "	17	32 N	146	20 W	278	38
Sept. 12, "	19	15 N	151	33 W	320	47
Sept. 13, "	21	19 N	156	43 W	320	48
Sept. 13, "	Arrived Honolulu...4·10 P. M.				73	10
Total.....	....				5,200	†703

* Sept. 11th had target practice.

†The coal given in the columns was by the hourly tally. Inspection of the bunkers after arrival at Honolulu showed that the amount actually expended was 747.44 tons, so that the daily amounts in the columns should be increased by 6.3 per cent.

Difference of time between Callao and Honolulu, hours and minutes	5·22
Total distance steamed (not including steaming during target practice), knots	5,200
Total time (deducting time spent in target practice), days, hours and minutes	18·1·17
Average speed per hour, knots	12
Coal consumed per 24 hours, tons	41.51
Number of knots per ton of coal	6.9
Pounds of coal per knot	321.95
Kind of coal	Cardiff, Ocean Merthyr.
August 26th to September 8th under boilers "A" and "B."	
September 8th to September 13th under boilers "C" and "D."	
Number of revolutions made by starboard engine	1,752,038
Number of revolutions made by port engine	1,748,387
Average revolutions per minute (mean of both screws)	67.325
Mean I.H.P. (both engines and auxiliaries)	1,519.00
Coal per I.H.P. of main engine and engine-room auxiliaries (deducting 3.5 tons per diem for galley, distilling and auxiliaries outside of engine room), pounds	2.33
Slip, per cent. (mean of both screws)	11.43
Mean draught for voyage, feet and inches	21–4.5
Mean displacement for voyage, tons	4,995

The distilling amounted to an average of 1,440 gallons of water per diem.

The forced-draft blowers were run for ventilation (discharging into open fire room) all but the last three days; for these an air pressure of 0.4 inch of water was maintained.

Olympia—The contractors' preliminary trial was made in Santa Barbara Channel on November 9th with excellent results, which promise an admirable performance on the official trial. The vessel had not been docked for some time so that there was a considerable growth of grass and barnacles on the bottom. In spite of this, however, the mean of two runs over the forty-knot course in the channel was 20.54 knots, while for a short time she made a speed of 21.26 knots. The contractors believe that with a clean bottom on the official trial, when the firemen will do their best, she will make fully 21.5 knots.

The following data of the engine performance are kindly supplied by Mr. W. R. Eckart, consulting engineer to the Union Iron Works:

FIRST RUN.

(Mean of five sets of Cards.)

	Starboard.	*Port.*
Steam at enginges (per gauge) pounds	134.4	137.0
Steam at 1st receiver (per gauge) pounds	58.4	59.2
Steam at 2d receiver (per gauge) pounds	10.2	13.6
Vacuum in inches	25 5	26.0
Revolutions per minute	129 88	128.00
Mean pressure reduced to L.P., and subject to correction, pounds	36 88	37.36
I.H.P. (subject to correction)	6,739 49	6,701.28
I.H.P. both main engines	13,480.38	

SECOND RUN.

(Mean of four sets of cards.)

	Starboard.	*Port.*
Steam at engines, per gauge, pounds	147.75	148.25
Steam at 1st receiver, per gauge, pounds	63.75	66.25
Steam at 2d receiver, per gauge, pounds	12.50	15.00
Vacuum in inches	25.3	25.6
Revolutions per minute	133.00	132.67
Mean pressure reduced to L.P. and subject to correction, pounds	39.94	41.07
I.H.P. (subject to correction)	7,485.43	7,657.28
I.H.P. both main engines	15,109.57	

Oregon.—This coast-line battleship was launched from the Union Iron Works, at San Francisco, on the 26th of October. She is a sister ship in all respects to the *Indiana* and the *Massachusetts*, which have already been described in the JOURNAL, p. 492, vol. V.

Montgomery.—This vessel was to have been tried over the course in Long Island Sound, October 3d, but just as she was approaching the harbor of New London on the evening before she ran aground, and so damaged the bottom that a trial was out of the question. After getting off, she returned to Baltimore without assistance, where the Columbian Iron Works are now repairing the damage. Owing to this trial not having taken place, the joint article on the trials of the *Detroit* and the *Montgomery* is still further postponed.

Columbia.—The triple-screw cruiser *Columbia* made her official trial on Saturday, November 18th, over a course nearly 44 knots long, the same as that recently used on the *New York's* trial,

with two knots added. The performance of the engines was excellent in every way, there not being a heated bearing or any other mishap. There was slight foaming in the auxiliary boilers, which made it necessary to slow the engines momentarily.

The mean speed for the two runs over the course, after applying the tidal correction, was 22.80 knots, being 1.8 knots above the contract requirement, which will earn a premium of $350,000. It would be a great error, however, to suppose that this amounts to a gift of that sum to the contractors. When the vessel was designed the machinery was made sufficiently powerful to secure 22 knots in smooth water, with everything in perfect order, and with the best skill for running off the trial, but unless there was perfection in every particular it could not be attained. The contractors for the *Columbia*, the Wm. Cramp & Sons' Ship and Engine-Building Company, can count not only on perfection of workmanship, but on the most skillful trial crew in this country. Knowing, therefore, that they could rely upon the best of everything, barring ill-luck, it is safe to say that they discounted a large part of the premium in their bid.

Besides taking the speed over the measured course, patent-log readings were obtained, which showed, as a mean, a total distance run of 93.96 knots in 231.75 minutes, or 3.86 hours. This gives a mean speed by patent log of 24.34 knots. This figure should be noted, because the trial speeds of all English naval vessels have been for some time obtained by patent log, and when the *Columbia's* speed is compared with theirs this figure of 24.34 knots should be used. Her actual speed is the greatest for any cruiser in the world over a long course, and her patent-log speed is far ahead of anything else.

The mean draught for the trial was 22 feet 6 inches, and the displacement 7,375 tons.

It will be noted from the table below that the central screw did not make as many revolutions as the side screws. The same phenomenon was observed on the trials of the *Kaiserin Augusta*. This result is exactly the opposite of what was anticipated by many, who believed that the "race" from the side screws would have the effect of making the central screw run faster than they.

SYNOPSIS OF ENGINE ROOM LOG.

	Port.	*Center.*	*Starboard.*
Revolutions of main engines per minute	132.9	127.68	134.
Steam pressure in boilers, per gauge, pounds	147.2	147.2	47.2
Steam pressure at first receiver, absolute, pounds	62.	63.5	75.
Steam pressure at second receiver, absolute, pounds	25.4	22.7	29.2
Steam cut-off in H.P. cylinder from beginning of stroke	.4	.6	.6
Steam cut-off in I.P. cylinder from beginning of stroke	.7	.7	.7
Steam cut-off in L. P. cylinder from beginning of stroke	.7	.7	.7
Opening of throttle valves, in tenths	10.	10.	10.
Vacuum in condenser in inches of mercury	25.6	25.	25.1
Barometer	29.78	29.78	29.78
Temperature of engine room	75 4	87.	84.
Temperature of injection water	49.	49.	49.
Temperature of discharge water	115 8	118.	134.2
Temperature of feed water	100.	115.	109.3
Temperature of fire rooms		105.7	
Air pressure in inches of water in fire rooms		.73	
Revolutions of blowers per minute in fire rooms		349.5	

PROPELLERS.

Diameter, feet	15.	14.	15.
Pitch as set on trial, feet and inches	21–6	21–6	21–6
Ratio, pitch to diameter	.698	.651	.698
Helicoidal area, square feet	53.7	53.28	53.7
Percentage of slip	19.13	15 85	19.82

On the day after the official trial, November 19th, while returning to Philadelphia, an eight-hour coal consumption trial was carried out, using the two side propellers, the central one being disconnected and allowed to revolve freely. The four after boilers were used with forced draft of the same intensity as on the official trial, viz: 0.73 inch of water. The mean speed for the eight hours was 18.87 knots.

The following is the engine-room log for the eight hours:

	Port.	*Starboard.*
Revolutions per minute	116.1	112.97
Steam pressure in boilers	131 9	131.9
Steam pressure at first receiver above perfect vacuum	48.5	50.2
Steam pressure at second receiver above perfect vacuum	18.8	20 1
Steam cut-off in H.P. cylinder from beginning of stroke	.50	.50
Steam cut-off in I.P. cylinder from beginning of stroke	.70	.70
Steam cut-off in L.P. cylinder from beginning of stroke	.70	.70
Opening of throttle valve in tenths	10.	10.

	Port.	*Starboard.*
Vacuum in condenser, in inches of mercury	25.7	24.5
Barometer in engine room	30.00	30.00
Temperature of engine room	77.6	78.
Temperature of injection water	48.1	48.1
Temperature of discharge water	128.	130.6
Temperature of feed water	111.3	86.1
Double strokes of air pump	14.9	15.
Revolutions of circulating pump	132.7	105.
Revolutions of center shaft (uncoupled)	72.8	
Square feet of grate surface in use (four after boilers)	672.	
Square feet of heating surface in use	22,316.72	
Pounds of fuel burned per hour	17,610 9	
Pounds of fuel burned per square foot G.S. per hour	26.2	
Air pressure in fire rooms, in inches of water	0 73	
Speed of ship, knots per hour	18.87	

In the next number of the JOURNAL will be given a full account of the trial of the *Columbia*, with description of hull and machinery.

GUNBOATS 7, 8 AND 9.

Bids for the construction of *Gunboats Nos. 7, 8 and 9*, authorized at a cost of $400,000 each by the current Naval Appropriation act, were opened at the Navy Department October 17th. The bids were as follows:

Maryland Steel Company of Baltimore—*Gunboat No. 7*, $380,000; either *Gunboat No. 8* or *No. 9*, $380,000; *Gunboat No. 7* and either *Gunboat No. 8* or *No. 9* $758,000; *Gunboats Nos. 8* and *9*, $750,000; all three gunboats, $1,110,000.

John H. Dialogue & Son of Camden, N. J.—All three gunboats, $1,186,000.

Union Iron Works of San Franscisco.—*Gunboat No. 7*, $400,000; either *Gunboat No. 8* or *No. 9*, $385,000; *Gunboat No. 7*, and either *Gunboat No. 8* or *No. 9*, $785,000; *Gunboats Nos. 8* and *9*, $700,000; all three gunboats, $1,100,000.

Coronado Foundry and Machine Company of Coronado, Cal.—*Gunboat No. 7*, $372,000.

Bath Iron Works of Bath, Maine.—*Gunboat No. 7*, $425,000; either *Gunboat No. 8* or *No. 9*, $468,000.

Newport News Shipbulding and Dry Dock Company of Newport News, Va.—*Gunboat No. 7*, $290,000; either *Gunboat No.*

8 or *No. 9*, $306,000; *Gunboat No. 7* and either *Gunboat No. 8* or *No. 9*, $585,000; *Gunboats Nos. 8* and *9*, $575,000; all three gunboats, $840,000.

All of the foregoing bids are for the construction of the vessels in accordance with plans prepared at the Navy Department. Bids for construction under plans of the bidder were submitted as follows:

Union Iron Works.—*Gunboat No. 8* or *No. 9*, $377,000; for both, $684,000; for all three, $1,084,000.

Bath Iron Works.—*Gunboat No. 7*, $368,000; either *No. 8* or *No. 9*, $382,000; *Gunboats Nos. 8* and *9*, $754,000.

The Newport News Company are the lowest bidders in each instance.

GREAT BRITAIN.

Majestic and Magnificent.—A Parliamentary paper gives the following description of the two first-class battleships, *Majestic* and *Magnificent*, to be built at Portsmouth and Chatham, and for the commencement of which provision is made in the Navy estimates for 1893–4: Their principal dimensions are as follows: Length, 390 feet; breadth, extreme, 75 feet; mean draught, 27½ feet; displacement, 14,900 tons. With natural draft on the eight hours' contractors' trial a mean speed of 16½ knots is anticipated; with moderate forced draft a maximum speed of 17¼ to 17½ knots will be obtained. The armament will include four 12-inch breech-loading guns of new type, mounted in pairs, twelve 6-inch quick-firing guns, sixteen 12-pounder quick-firing guns, and twelve 3-pounders. There will also be five torpedo dischargers for 18-inch torpedoes, four of these being submerged. In the general disposition of the armament the arrangements of the *Royal Sovereign* class have been followed. There are, however, certain important differences. The 12-inch guns mounted in two strongly-armored barbettes will have their mountings so arranged that they can be loaded in any position by manual power, while the proved advantages available with hydraulic power, and fixed loading stations will be retained. Strong armored shields will also be fitted to the turntables and revolve with the guns. The protection of the 6-inch guns has been

carried out more thoroughly than in the *Royal Sovereign* class, involving considerable additional weight. Two more 6-inch guns are carried in the new ships, and 12-pounder quick-firing guns have been adopted instead of 6-pounders, as in the *Royal Sovereign*. The total weight of protective material on the hull, including protection of 6-inch guns and protective deck, is greater than the corresponding weight in the *Royal Sovereign* class.

Having regard to the improved qualities of armor now produced, and to the distribution and thickness of plating in the new ships, it is believed that they will possess unrivalled defense in close action, under existing conditions of attack or possible developments of high explosives and quick-firing guns. The *Majestic* and *Magnificent* have the same draught of water and extreme breadth as the *Royal Sovereign* class, but are 10 feet longer, and carry their heavy guns forward about 4 feet higher, having the freeboard correspondingly increased. They will be of practically the same speed, and are intended to carry on the designed load draught the same weight of coal as was proposed for the *Royal Sovereign*—900 tons. In the new ships the coal bunker capacity will be largely increased, as compared with the *Royal Sovereign* class, and provision made in the design for filling up the whole space when desired. The new ships will, therefore, possess greater coal endurance, and be capable of keeping the sea for longer periods. Although the substitution of 12-inch for 13½-inch guns has effected a considerable reduction in weight, the aggregate result of the changes above mentioned has involved a considerable addition to the load to be carried by the *Majestic* and *Magnificent*. It is anticipated that some of the changes made will tend to sensible economy in first cost, as compared with preceding vessels.

Resolution—The *Resolution*, a first-class battleship of the Royal Sovereign class, built and engined by Messrs. Palmer and Co., of Jarrow, went on Thursday, August 31, for a contractors' four hours' full power trial, under what is officially designated as modified forced draft. The difference between this and extreme forced draft may be concisely stated to be this, that whereas the

engines under the former condition are contracted to develop a mean of at least 13,000 horses, under the latter condition the contract is for 11,000 horses. There was a light wind throughout the day, with a perfectly smooth sea. The trim of the ship was 23 feet 10 inches forward and 25 feet 8 inches aft, giving a mean immersion of 24 feet 8 inches, or 2 feet 10 inches less than her designed load draught. The battleship got under way at eight o'clock, steering a direct course for Beachy Head for the purpose of obtaining a run in deep water, and shortly before nine o'clock everything was ready for the half-hourly observations to begin. The propelling engines are substantially of the same pattern as those of the other vessels of the class. The stroke is 51 inches, and the trial was made with the engines linked up to 31 inches. The screws are of the modified Griffith's type, having a diameter of 17 feet and a mean pitch of 18 feet 9 inches. The appended table shows the results of the observations for each half-hour steamed :

Boiler pressure.	Indicated horse power.	Revolutions.	Air pressure.
148	11,347	103	.62
150	11,580	104	.60
146	11,258	103	.60
157	11,468	104	.65
151	11,828	104	.78
151	11,620	105	.69
147	11,063	103	.78
147	10,894	102	.43

The following means were subsequently worked out : Steam in boilers, 148.8 pounds ; vacuum, 27.8 ; revolutions, 103.2 starboard and 103.8 port ; mean pressures, high, 52.37 and 52.73 ; intermediate, 26.06 and 26.35 ; low, 12.51 and 12.35 ; indicated horse power, high, 1,749 and 1,773 ; intermediate, 1,895 and 1,928 ; low, 2,024 and 2,010 ; total indicated horse power, 5,668 starboard, and 5,611 port. The collective indicated horse power was consequently 11,379, or 379 horses beyond the contract, a result which was obtained with a consumption of fuel (Harris' deep-sea navigation) amounting to 2.4 pounds per indicated

horse power per hour, and an air pressure in the stokeholds equal to .63 inch, or only a trifle in excess of the average used for natural draft. The mean speed realized during the four hours, as measured by "Cherub" log, was 17.92, the estimated speed under seagoing conditions being 17.5 knots. The engines were afterwards tested for stopping and starting, with the following results: From full speed ahead to stop, $7\frac{3}{4}$ seconds; full speed astern, $6\frac{3}{4}$ seconds; full speed astern to full speed ahead, $7\frac{3}{4}$ seconds; and also under various conditions of cut off. The trial was satisfactory in every respect.

Camperdown.—On the arrival on July 7th of the *Camperdown* at Malta, after her unfortunate collision with the *Victoria*, she was docked, and an examination made of the injuries she had sustained. These were found to be far less serious than was expected. They consisted of a hole in her port bow about ten feet by six, while the stem was cut right through about six feet above the ram and twisted over to port. The ram itself and the armored deck are uninjured, but the figure head is missing. The hole in the bows had been temporarily covered with three iron plates by the divers of the squadron. The method of fixing the plates is thus described: The divers wedged a dozen or more iron stanchions inside the collision compartment, and when these were firmly fixed the plates were secured to them by long bolts having hook-shaped ends. The straight end of the bolt was passed through a hole in the covering plate and secured by a nut. The smaller apertures were filled with wooden wedges tightly driven, and then the whole fracture was covered by a mat and canvas. A new stem piece for the ship will have to be forged, and this work may have to be done at home, but the dockyard authorities at Malta have energetically set about the business of repair, and every effort is being made to expedite matters. Gangs of men are working night and day, orders having been sent to get her finished as speedily as possible, and an apparently optimistic estimate of the time to be occupied in making good defects is nine weeks.

Ramillies.—The new battleship *Ramillies*, which is being completed as the flagship of the Commander-in-Chief of the Medi-

terranean Fleet, and which has been fully described in "Engineering," * has completed her gunnery trials with results eminently satisfactory, alike to the several constructors of the guns and the builders of the ship and engines—Messrs. J. and G. Thomson, Limited, Clydebank. In the first place, the diameters of the circles turned by the vessel were measured under various conditions of helms and propelling power, the ship being steered round a buoy, angles being taken at every four points turned by observers stationed at the bow and stern, using the known length of the ship as a base line. The gunnery trials were proceeded with on Wednesday. The main armament of the *Ramillies*, it may be said, consists of four 13½-inch 67-ton guns, Mark III. The secondary and auxiliary armaments comprise ten 6-inch 100-pounder quick-firing guns, sixteen 6-pounder and nine 3-pounder quick-firers, eight machine guns, and a couple of 9-pounder field guns—an aggregate about 500 tons heavier than the secondary armaments carried by battleships of the *Trafalgar* class. The 6-inch quick-firing guns are mounted in a central battery, and are double-banked. Four are disposed on the main deck within armor casemates 6 inches in thickness at the face, and having athwart screens for the protection of the gun crew. The forward guns are arranged to train 60 degrees ahead, and the after guns 60 degrees astern. The four 67-ton guns, which are of the same pattern, though constructed by different manufacturers, are mounted in pairs in a couple of barbettes erected at each end of the secondary battery, and consequently well apart. Although they tower to a height of not less than 23 feet above the water line, their tops protrude only 2 feet 9 inches beyond the level of the upper deck; and as the structures are screened by the top sides of the ship, they present an indifferent target to an enemy. The axis of the guns when laid horizontally is about a foot and a half higher than the parapets of the redoubts, or a total height of 4 feet 6 inches above the deck, which is believed to be sufficient to preserve it intact when the guns are fired direct ahead.

* "Engineering," vol. liv, pages 197 and 412; vol. lv, page 716. See also *Ibid.* vol. li, pages 251 and 283; vol. liii, pages 287 and 530.

The guns have a total length of 36 feet 1 inch, with a length of bore of 405 inches, equal to 30 calibers, while the rifling extends throughout a length of 333.4 inches. The powder chamber is 18 inches, the jacket 57 inches, and the chase at the muzzle, which has a slight bulge, 23.4 inches in diameter. The full charge fired weighed 630 pounds, S.B.C. powder, and the reduced charge 472½ pounds, while the projectile had an approximate weight of 1,250 pounds. The general details of the hydraulic machinery and arrangements are precisely of the same character and design as those employed on board the *Royal Sovereign*, it having been found impossible to improve upon them. The great object aimed at has been to combine quickness of fire with perfect safety in the working. The hoists are loaded with shot and powder from different sides simultaneously. This economizes time in feeding the guns; but as the path from the bogey to the lift has an upward inclination corresponding with the plane of the guns when the breeches are depressed for loading, the new system also offers additional security against accident, as there is no danger of the projectiles taking charge when being forced up the gradient and striking the stops against which they are to rest. It may be interesting to state that each of the 67 ton guns forming the main armament costs £13,000, exclusive of its mounting, and that every shotted round fired represents an expenditure of £114. The whole of the hydraulic machinery was designed, manufactured and fitted on board by Sir William Armstrong, Mitchell & Co., of the Elswick Ordnance Works.

Firing, according to the "Times" report of the trials, commenced with the machine, Hotchkiss, and 6-inch quick-firing guns on the upper deck. Fifty rounds were discharged from the first mentioned in pulls of five each, four 7¾-ounce charges from the 6-pounder, four 6⅜-ounce charges from the 3-pounders, and two charges of 13 pounds 4 ounces each from the 6-inch quick-fires. The mountings withstood the strains perfectly, and it is only necessary to record with respect to this part of the program, that cordite was exclusively used for the quick-firing guns. The trial of the 67-ton guns afterwards took place. The follow-

ing is a tabulated record of the order and conditions of firing, with the recoils of the guns for each round:

Barbette.	Gun.	Rounds.	Charge.	Elevation.	Bearing.	Recoils.
				deg.	*deg.*	*ft. in.*
After.....	Left gun.	1	Reduced.	5 elevation.	Port beam.	2 3½
		2	Full.	5 elevation.	10 before beam.	4 1
		3	Full.	Horizontal.	10 abaft beam.	4 1
	Right gun.	1	Reduced.	Horizontal.	Port beam.	2 3
		2	Full.	5 elevation.	10 before beam.	4 0
		3	Full.	Horizontal.	10 abaft beam.	4 0
Fore.....	Left gun.	1	Reduced.	Horizontal.	Starboard beam.	2 8½
		2	Full.	Extreme el'vation.	10 before beam.	3 5
		3	Full.	5 elevation.	10 abaft beam.	3 3
	Right gun.	1	Reduced.	Horizontal.	Starboard beam.	2 10½
		2	Full.	10 elevation.	10 before beam.	3 2
		3	Full.	5 elevation.	10 abaft beam.	3 7½

The hydraulic connections were worked at a pressure of 1,000 pounds, and it was understood that the maximum pressure in the recoil presses was about 2,700 pounds. The third rounds from the guns in the after barbette were fired simultaneously, and the whole of the others independently. The second round from the left gun in the fore barbette was fired with extreme elevation for the purpose of determining the maximum recoil. This was reported to be 41 inches. The recoils were, on the whole, eminently satisfactory, those of the guns in the after barbette uniformly so. There were no accidents of any kind, and with the exception of the breaking of a few panes of glass, no damage was inflicted upon the ship's fittings by the heavy concussions. The hydraulic machinery proved perfectly reliable under the demand made upon it, and showed no signs of distress. The 6-inch guns on the main deck were subsequently fired. The guns, in consequence of their great length, are fitted with an arrangement for running them in and completely housing them. The gear was not tried, but previous experiments had shown that the guns beneath the deck can be disconnected, suspended, and brought inboard in 3 minutes 42 seconds.

Centurion.—The *Centurion*, which was laid down at Portsmouth in March, 1891, and engined by the Greenock Foundry Company, went out from Spithead on the 19th of September for her contractors' eight hours' trial with natural draft. She is of

10,500 tons displacement, and forms, with her sister ship, the *Barfleur*, a distinct type of first-class battle ship. Of light draught compared with most armorclads of her size, she was designed to be able to pass through the Suez Canal with a large quantity of coal on board, being in all other respects fully laden. Her mean load immersion is 25 feet 6 inches, and her estimated speed in this condition under natural draft is 17 knots. Her trim on trial was 25 feet forward and 26 feet aft, so that the average draught was exactly that of her designed draught. The trial proved eminently satisfactory. With a boiler pressure of 146½ pounds and a mean of 96 revolutions the starboard engine developed 4,785 and the port engine 4,918 horses, or a total collective horse power of 9,703. The contract was for 9,000. The mean air pressure amounted to 0.18 inch, and the coal consumption to 1.9 pounds per indicated horse power per hour. The average speed realized during the eight hours' steaming was 17½ knots by log. The engines have been designed to indicate 13,000 horse power with fored draft. Her cost for hull and machinery will be about £608,000. Her armament will consist of four 29-ton guns, ten 4.7-inch quick-firing guns, and a formidable array of light weapons and machine guns, besides two submerged torpedo tubes. The forced-draft trial, which followed the natural-draft trial, was less successful, as the engines did not develop their contract force of 13,000 horse power. A further trial will be carried out in about a fortnight, and it is expected that the contract power will be ultimately attained.

The *Centurion* made her four hours' continuous steam trial under forced draft on Friday the 6th of October, betwen the Warner Lightship and Beachy Head. Since the previous trial of the *Centurion* ¼ inch had been taken from the tops of the slide valves to admit more steam into the high and the low pressure cylinders, the eccentrics had been readjusted so as to relieve the exit of the exhaust steam, and the reported leakages in the stokeholds, which detracted from the useful work of the fans, had been stopped. There was little wind and a smooth sea. The following are the details of the four hours' steaming:

Boiler Pressure.	Air Pressure.	Revolutions.		Indicated Horse Power.
		Starboard.	Port.	
145	1.5	105.	104 5	12,954
147	1.6	106.	105.8	13,581
146	1.3	105.	105 6	13,010
147	1.5	104.9	105.0	13,246
146	1.5	104.4	104.3	13,494
147	1.7	104.6	104.7	13,139
146	1.7	104.6	104.7	12,766
144	1.7	103.6	103.9	13,202

Owing to the premature commencement of the trial, and the consequent throttling of the steam, the first half-hour was somewhat disappointing, and it was thrown out. There was also a falling-off in the power developed during the fourth half-hour, owing to a changing of stokers, but, with these exceptions, the periodical returns were highly gratifying throughout. Subsequent calculations by the staff on board gave the appended means: Steam in boilers, 146 pounds; vacuum, 27.6 inches starboard and 27.1 aft; revolutions, 104.7 starboard and 104.8 port, displaying remarkable uniformity in the action of the two sets of engines; total indicated horse power, 6,401 starboard and 6,773 port, representing a collective horse power of 13,174, or a margin of 174 beyond the contract. The mean air pressure was 1.58 inches, and the coal consumption 2.24 pounds per indicated horse power per hour. The average deep sea speed of ship, as recorded by log, was 18.51 knots, which, though believed to be below the actual performance, is the greatest speed which has hitherto been attained by an armor-clad.

Devastation.—The *Devastation*, after undergoing a thorough renovation and reconstruction in hull, machinery and armament at Portsmouth, made her eight hours' steam trial under natural draft on Tuesday, the 12th of September. Her trim was 25 feet forward and 26 feet 8½ inches aft. The average boiler pressure was 140 pounds, and the mean vacuum was as high as 28.2 inches starboard and 28½ inches port. With 94.4 and 93.2

revolutions the engines developed an indicated horse power of 3,139 and 2,861, giving a collective mean power of 6,000 horses, or, in other words, 500 beyond the contract. The mean air pressure in the stokeholds was ½ inch, and the coal consumption 1.8 pounds per horse power per hour. The speed obtained was 13.25 knots, as taken by patent log. The trial was satisfactory, though the speed was slightly under the estimate. The rehabilitation of the earliest of our sea-going mastless turret ships, built in 1869–72, must be regarded as a noteworthy naval event. The central internal portion of the hull has been rebuilt. This modification involved the rearrangement of the main watertight subdivisions, the construction of additional coal bunkers, the fitting of new watertight doors and gearing, and boiler, engine, shaft, and thrust bearings, new casings between decks, and new ventilating arrangements. The ship has been furnished with a modern installation of electric lights. A fighting platform or military top has been added to her mast. This enables a couple of 3-pounder quick-firing guns to be mounted in one of the most effective positions on board. The new armament is as follows: Four 10-inch 29-ton breech-loading guns, two 7-pounder 200-pound guns, six 6-pounder quick-firing guns, eight 3-pounder quick-firing guns, five 5-barrel .45-inch Gardners, twelve 14-inch torpedoes, two submerged tubes, "A" proportion of torpedo and electrical stores. The new machinery for the *Devastation* has been furnished by Messrs. Maudslay, Sons & Field. In her unreformed condition the monitor was propelled by engines of the direct-acting trunk type, supplied by Messrs. John Penn & Sons, Greenwich. The new propelling machinery consists of two sets of inverted triple-expansion engines, of the collective power of 5,500 with natural draft, and 7,000 with forced draft. The cylinders are 34½ inches, 51 inches, and 76 inches in diameter by 42 inches stroke. The condensers have a total cooling surface of 9,000 square feet, and the working pressure of the main boilers is 140 pounds on the square inch. With natural draft the estimated speed of the ship was 13.4 knots, and it is expected that with forced draft a speed of 14 knots will be obtained. In the Navy Estimates the proba-

ble cost of the *Devastation's* refit is given at £156,261, including £67,555 for hull fittings and equipment, £63,187 for machinery, and £11,324 for gun mountings and torpedo gear.

The four hours' full-power trial under forced draft took place on Thursday, the 14th of October. The engines were worked for the four hours linked up a couple of inches, and with a greater head of steam than they could use, as it was not deemed necessary to test them beyond the power which they were contracted to develop. They worked satisfactorily throughout, the vacuum being exceptionally high and the revolutions of both sets of engines uniform. The cards were worked out with the following results, from which it will be noticed that during only one half-hour did the power indicated fall below the contract:

Boiler Pressure.	Revolutions.		Air Pressure.	Horse Power.
	Starboard.	Port.		
Pounds.			*Inches.*	
145	99.5	100.0	.8	7,166
145	99 8	100.9	.9	7,405
140	100.4	100.0	.7	7,029
141	103.3	99.7	1.1	7,266
140	103 3	101.2	1.1	7,514
135	101.5	102.5	1.15	7,172
143	97.5	97 8	1.4	7,990
144	100.7	101.8	1.1	7,175

The above data gave the following means: Steam in boilers, 141.6 pounds; revolutions, 100.2 and 100.7; vacuum, 28.4 inches and 28.5 inches; indicated horse power, starboard, 3,727, and 3,847 port; collective indicated horse power, 7,214 (contract power, 7,000). The average air pressure was 1.03 inches, the maximum allowed being 2 inches; and the coal consumption, 2.1 pounds per indicated horse power per hour. The speed realized, as measured by patent log, was 14.56 knots.—"London Times."

The *Devastation* has completed her gunnery trials. The mountings for the 10-inch 29-ton breech loaders in the turrets

differ from all others hitherto supplied to the Navy in the arrangement of the recoil appointments. The new guns have a total length of 342.4 inches, a length of bore (including powder chamber) of 320 inches, and a diameter of 43 inches at the breech tapering to 16 inches at the muzzle, and they fire a projectile weighing 500 pounds, with a full charge of 252 pounds of prismatic brown powder. The muzzle velocity is 2,040 feet per second, and the muzzle energy 14,430 foot-tons. In the *Devastation* the turret armament is worked entirely by hand, and in consequence the guns can be loaded at any time and in any position. The turrets, however, are rotated by steam, and during her refit a duplicate turning engine has been attached to each turret as a precaution against accident. Four rounds were fired from each of the eight 3-pounder Hotchkiss quick-firing guns. Three rounds were afterwards fired from each of the guns in the fore and after turrets, two independently with reduced and full charges, and the last from each gun simultaneously with full charges. The elevation rose from horizontal to as much as 13 degrees extreme elevation, while the bearings varied from abeam to 10 degrees before. to 20 degrees abaft the starboard and port beam respectively. A number of misfires occurred, owing to the use of wire tubes, and in the fore turret there was a little scoring of the brake piston by the glands, which caused some delay. The trials, however, passed off with remarkable success. The recoils from all the guns remained uniform at 36½ inches with full, and at 36¼ inches with reduced charges, while the graphic lines and curves of recoil pressures showed that the action of the bar regulating the influx of water in the brakes was particularly steady. The under-water torpedo gear was subsequently tested.

Theseus.—The *Theseus* is a first-class cruiser, one of the last ships of the Hamilton program. She has been built by the Thames Iron Works and Shipbuilding Company at Blackwall, and has just been completed in the Victoria Docks.

The *Theseus* is 360 feet long, 60 feet wide, and has a mean draught of 23 feet 9 inches, the displacement at this draught being 7,391 tons. The engines indicate 12,000 horse power and give the vessel a speed of 19¾ knots under forced draft.

Like other ships of her class, she has no side armor, but the usual protective steel deck is worked in, the maximum thickness being 5 inches. To protect the engine cylinders, which come above the water level, there is an inclined armored breastwork of 6-inch steel. This is backed by 3 inches of teak and 1½ inches of plating. The coal bunkers are arranged as usual, so as to supplement this protection. The protective deck has a maximum thickness of 5 inches, where the greatest protection is required, tapering to 2 inches. The 5-inch parts are made up of two thicknesses of 1¼-inch plates and one thickness of 2½-inch plates. The deck beams are of angle bulb, which, in the midship part, have a 9-inch vertical flange and 3½-inch horizontal flange, while in the forward and after parts the depth is 7 inches. There is a beam to every frame, and the attachment of beam and frame is strengthened by gusset plates. The frames are of Z-section, 3½ inches by 6 inches by 3 inches, the latter being the reverse flange. The plating is 15 pounds above the water line, the sheer strake being double, and 22.5 pounds below the water line, but the skin is doubled over the greater part of its area, all the bow being flush on the outside. The double bottom extends over the whole of the machinery and magazine spaces. The inner keel plate is $\frac{7}{16}$ inch and the outer $\frac{5}{8}$ inch. The vertical web is ½ inch in thickness. There are four longitudinals on each side of the keel. The main deck, which is of wood, has steel stringers about 3 feet 3 inches wide. The main and upper deck beams are of T-bulbs, 8 inches deep and 5 inches horizontal flange amidships, and 7 inches forward and aft, but under the 9.2-inch guns they are 9 inches deep. There are eighteen main compartments, divided by bulkheads, all of which can be made watertight by closing the doors. The conning tower is made of two rolled steel plates 12 inches thick, another plate protecting the entrance. Each of the two conning-tower plates weighs 25 tons. On the poop, aft of the chart house, there is a steel-plated torpedo-director tower, which is of oval section. On the main deck there are four search-light towers. These are so arranged that they can be entirely closed by water-tight doors, so as to isolate them from the deck, and thus prevent water entering the ship.

The armament consists of two 9.2-inch 22-ton breechloading guns, one on the poop and the other on the forecastle. These are mounted on the central pivot system, the arc of fire being 240 degrees; the ammunition is brought up through the mounting. There are ten 6-inch quick-firing guns, throwing 100-pound projectiles. Five are mounted on each side. There are eight 6-pounder quick-firing guns, and eight 3-pounder quick-firing guns. In addition to these there are two 9-pounder field guns and five .45-inch Nordenfeldt guns. This makes thirty-five guns in all. There are also four 14-inch torpedo guns, two being fitted below water forward, and two above water aft. The under-water torpedoes are fired from the conning tower, and those aft from the director tower. There are, for the torpedo service, three Brotherhood air compressors, which work to 1,700 pounds pressure to the square inch. The steering engine is placed aft, below the protective deck. Arrangements have been made for alternate methods of working the rudder. The gear can be changed from steam to hand gear in the usual way, but should the main steering screw of the gear become damaged, the connecting rods of the crosshead on the rudder can be disconnected and attached to tackles provided for the purpose. These can be worked either by the hand wheels or by the steering engine, the falls being led over a barrel. Should the engine be disabled, or the hand wheel break down, the rudder can be actuated by the tackles direct, eye-bolts for luff tackles being placed in the bulkheads. In all, there are five distinct methods of steering, so that as long as the rudder itself holds good there are four alternatives if the main gearing is out of order. The steam gear will put the rudder from hard-a-port to hard-a-starboard in thirty seconds, with the ship going at full speed. There is the usual helm indicator on the mast, of which we have heard so much lately in regard to the *Victoria* disaster. This, as most of our readers doubtless know, consists of a continuous wire rope, which winds over a barrel attached to the steering gear. Half way up the mast, attached to the rope, is a flag on one side, and on the other there is a cone. As these ascend or descend, other vessels are able to tell whether the ves-

sel's helm is port or starboard. In action the steering can be done either from the hand-steering compartment below or from a protected position forward.

An ingenious arrangement has been introduced for ventilating openings to the magazines. In consequence of the hygroscopic properties of the new powder, it is desirable that places where it is stowed should be well ventilated. At the same time openings into magazines are not desirable, on account of danger in case of fire. In order to meet the case, a ventilating box, having a valve which can be easily closed, is placed on the magazine. This box is connected with the ventilating trunk, and, under ordinary circumstances, the airway is open. There is, however, a ball which will form a valve to close the airway. A pipe leads from the upper deck down to this box, and, on an alarm of fire, it would be the duty of certain persons to at once pour water down this pipe. This water, entering the box, on the bottom of which the ball rests, would cause the latter to be floated up until it assumed a position closing the airway, so that there would be no danger of sparks being carried into the magazine by the ventilating current. Domestic ventilation in this ship, as in all of her class, is very perfect; the main ventilation trunk is square in section, and is carried from end to end beneath the protective deck, going right into the fore peak and into the rudder compartment aft. Its cross-sectional area amidships is 300 square inches, the dimensions being 30 inches by 10 inches. It tapers at the ends to a sectional area of 50 square inches. The branch pipes to the various compartments are circular in section. There are two 5-foot ventilating fans for this trunk. Where the trunk passes through bulkheads there is a device for closing the slide door of the nature of a sluice valve in construction. As in the case of the closing apparatus for the magazine, this is worked by pouring water down a pipe, provided for the purpose, from the deck above. On the back of the valve or shutter there is a rack, and into this a pinion gears. The pinion is actuated by a lever, to the end of which is fixed a float, the float resting in a chamber. When it is desired to close the door from above, so as to shut off the

opening in the bulkhead necessary for the passage of air, water is poured down the pipe from above and falls into the float chamber. This causes the float to rise, and, as it rises, it works the pinion, so starting the shutter or watertight door, which then falls the rest of its travel by its own gravity. In the steering compartment aft is kept a small portable hand fan, which is placed on a carriage on wheels. There are two of these fans, and they are used for ventilating any small compartments. The coal bunkers have a system of ventilation of their own, pipes being carried from them into the funnel casing, so that the circulation of air depends on the natural draught, due to the heat given off by the funnel. All openings in the protected deck are sheltered by double cofferdams, and the armored hatches, with which the openings are fitted, are balanced so that they can be easily opened from below.

The ground tackle consists of three 92-cwt. anchors by Brown, Lennox & Co., whilst there are smaller anchors of the ordinary Admiralty pattern. The windlass and capstans are by Harfield, and are suitable for 2⅛-inch cables. They can be worked by steam or hand. The windlass will work a cable at each of the two hawsepipes at once. The starboard and port cables can be veered and hauled at the same time, and the windlass and capstan will work together or independently. There is a hand-power capstan on the quarterdeck. There are fifteen boats, the largest being a 56-feet vidette boat, a class of vessel that has taken the place of the old second-class torpedo boat with advantage, being a much more useful although a heavier craft. There are two steam winches for handling the boats. The vessels of the *Theseus* class are fitted with two pole masts, and are lightly rigged as fore-and-aft schooners. The chief use of the masts, however, is for signal purposes and to act as crane posts, there being a large iron derrick on the mainmast for boat-hoisting purposes. For the supply of electric light there are three Siemens dynamos, each capable of giving a steady current of 400 ampères. They run at 320 revolutions a minute, and are actuated by Brotherhood engines, coupled direct. The current is 80 volts at terminals.

The propelling machinery is by Maudslays, each set of engines being placed in a separate engine room, as usual. They are of the ordinary inverted, vertical, three-cylinder, triple-compound type. The cylinders are 40 inches, 59 inches, and 88 inches in diameter, the stroke being 51 inches. Ordinary double-ported slide valves are used, actuated by eccentrics in the usual way, solid bar-link motions being used. The cylinders are supported in front by cast-steel columns, each engine of the set being independent of the other, so that each cylinder has its separate bed plate. The cylinders are, however, stayed to each other and to the engine-room bulkheads. The main and auxiliary steam pipes are of copper, and are bound with wire. The shafting is of hollow forged steel. The crank shafts are in three pieces, and interchangeable. Each set of engines has a gun-metal air pump, 33 inches in diameter, worked by the low-pressure piston. There are two brass condensers, having 13,500 square feet of cooling surface, the steam passing through the tubes. For circulating water there are four centrifugal pumps, each capable of delivering 1,000 tons of water per hour. The usual interchangeable system of suction and delivery is adopted, so as to draw either from the bilge or from the sea, and to deliver into either condenser, as required. For the auxiliary engines there are two horizontal brass surface condensers, having a cooling surface of 1,600 square feet. There are, for all purposes, eight single-ended boilers, each 16 feet 2 inches in diameter and 9 feet 10 inches long, having four corrugated steel furnaces of 3 feet 7 inches mean diameter. The aggregate tube surface in all the boilers is 21,400 square feet, and the fire-grate surface 855 square feet. The working pressure is 155 pounds to the square inch. The designed coal bunker capacity is 1,000 tons, although, we believe, there is room for more than this quantity. The usual closed stokehold arrangement for forced draft is fitted, there being eight forced-draft fans, each 5 feet 6 inches in diameter. The fresh-water distillers and evaporators for domestic purposes have a combined capacity of 540 gallons of fresh water per hour.

It is satisfactory to find that the Thames can still turn out warships of the highest class. In naval engines the metropolitan river still holds her own, but for big war vessels the London district—once so great a center of iron shipbuilding—has now to depend on the Thames Iron Works alone, there being no other establishment which, at present, builds large craft of this nature, although in the smaller vessels of the Navy the firms of Thornycroft and Yarrow put the London district in the foremost position. The existence of the Thames Iron Works is really a matter of national importance, it being highly desirable that yards capable of building large warships should be distributed over the country. Were it left to commercial considerations alone, doubtless the building of big ships would leave the southern part of the kingdom in favor of the north, but for strategical purposes it is necessary that there should not be concentration of building yards in any one part of the kingdom. Within recent times the Thames Iron Works has built the *Benbow*, *Sans Pareil*, the *Blenheim*, the *Grafton* and the *Theseus;* whilst it will be remembered that our very first ironclad, the *Warrior*, was launched from the famous slips at the mouth of Bow Creek. Another vessel which will become historical, although still in active service, was constructed at this yard. The *Himalaya*, we are reminded, has just completed her fortieth year of service, having been launched at Blackwall on May 28, 1853. She was built for the P. & O. Company, but the vessel proved a most valuable accession to our national resources at a time when they were put to some strain. The length of the *Himalaya* is 340 feet between perpendiculars, her breadth 46 feet, and her depth to the top of the keel 34 feet 4 inches; the load draught is 20 feet 6 inches. The displacement is 4,392 tons. The engines are of 2,600 horse power, and were constructed by the historic firm of Penn. The speed is 13.9 knots. These figures seem moderate enough in the present day, but those of our readers who can carry their recollection so far back will remember how ambitious a step was then considered to be embodied in the design of the *Himalaya*, and it was thought that the P. & O. directors had altogether overstepped the limits of prudence. Commencing

with the *Himalaya*, no less, we are told, than sixty-five vessels have been built by the Thames Iron Works for the British Admiralty. The total displacement of them is 113,243 tons. Sixty-eight vessels have also been built by this firm for foreign governments, with a total displacement of 75,000 tons. These are all naval vessels, but in addition to them 696 ships have been constructed for the mercantile marine.—" Engineering."

Havock.—On October 28th a trial took place, which has been anticipated for some time with interest, perhaps not quite without a tinge of anxiety, by many of those responsible for the efficiency of vessels in Her Majesty's Navy. The craft making this trial was the first of the new class of swift torpedo-boat destroyers; the conditions to be fulfilled by these boats having been laid down by Dr. W. H. White, the Director of Naval Construction, and contractors were invited last year to make proposals for them. When it is stated that the stipulated speed was 26 knots, with a load of 35 tons on board, if locomotive-type boilers were used, and 27 knots under the same conditions of trial in other respects, if water-tube boilers were adopted—the trial being for three hours' continuous run—it will easily be understood that the field of selection open to the Admiralty authorities was somewhat restricted, in fact it was confined at first only to the two well-known Thames firms of Thornycroft and Yarrow, although Laird Brothers have more recently secured an order for two boats of a similar type. Messrs. Yarrow undertook to build two of these novel vessels, and these are now known as the *Havock* and the *Hornet;* the former, which is the vessel tried on the date mentioned, has locomotive-type boilers, and the *Hornet* the Yarrow water-tube boiler. Those who have followed our accounts of the naval manœuvres of recent years will remember the drawback to the ordinary first-class torpedo-boat which results from the loss of speed experienced by these vessels when running in anything like a heavy sea. Naval officers were not slow to grasp the possible effect this would have in reducing the efficiency of torpedo-boats, and it was doubtless largely due to this that a pause was made in the construction of these vessels. The present Controller, Admiral

Fisher, has contended for some time that a larger and more powerful craft of the torpedo-boat type might secure the speed at sea required to overhaul existing torpedo-boats. The problem was put before the Director of Naval Construction, who determined upon the present class of vessel. The result of the *Havock's* trial has more than justified his expectation, although there were many authorities in this field who doubted the possibility of what is now an accomplished fact.

We have already given particulars of Messrs. Yarrow's two vessels,* but we will now repeat the leading elements of design for convenience of reference. The boats are twin screw, and generally resemble the first-class torpedo-boats built by this firm. The length is 180 feet and the width 18 feet 6 inches. There is the usual hood or turtle back forward, although some modifications have been introduced with a view to getting a drier deck when the vessel is steaming into a head sea. We hope to illustrate these boats at a later date, and may, therefore, leave these details for the present. The propellers are three-bladed. The engines are of the usual tri-compound type adopted by the firm, having cylinders 18 inches, 26 inches, and 39½ inches in diameter, by 18 inches stroke. The boilers, two in number, as stated, are of the locomotive type, and have copper fireboxes with copper tubes. The total grate surface is about 100 square feet, and the total heating surface about 5,000 square feet.

Saturday's trial was made in what was decidedly heavy weather. The speed of the wind was put down at 30 miles per hour, and the trial was made in the open sea, the Maplin course being used for the measured mile runs, while the rest of the trial was run off shore into the German Ocean, so the boat was not favored by fair weather conditions. Messrs. Yarrow have somewhat of a reputation for taking people by surprise, and so it has been in this case, for it was only last week we made inquiries as to when the trial would take place, and were told it would not probably be for some weeks. Now it appears that at the last moment it was decided to run on Saturday, and for that

* See "Engineering," vol. lv, page 848.

reason we missed the opportunity of witnessing this unsurpassed performance, and thus broke our own record of having been present at all the "record" trials of this class of boat for some years past. The following is a copy of the observed results as to speed on the last four runs made on the mile, the deadweight on board being 35 tons. If the load carried were estimated in the manner customary with foreign powers, it would be even greater than this.

On the three hours' run, made under the exceptionally trying conditions of weather referred to, the speed was over 26 knots. On the runs on the mile the mean revolutions were about 362 per minute, and the indicated horse power was approximately 3,400, although at the time of writing the cards have not all been worked out. The figures, however, may be taken as a fairly close approximation, as it is further supported by data obtained on preliminary trials.

Time.	Speed.	Mean Speed.	Second Means.	Final.
min. *sec.*				
2 10·6	27.565			
		26.695		
2 19·4	25.825		26.684	
		26.673		26.783
2 10·8	27.522		26 883	
		27.094		
2 15	26.666			

Although the speed is so eminently satisfactory, we think Messrs. Yarrow could, had they wished, have gone a little—perhaps a good deal—higher. The designed boiler pressure, as stated, was 180 pounds, but during the trial the mean recorded pressure was 165 pounds per square inch, being 15 pounds below the maximum. This, we understand, was not owing to the fact that there was difficulty in obtaining a greater supply of steam, as the air pressure was moderate for this kind of boat, between two and three inches of water, the maximum allowed by the Admiralty being 5 inches, but owing to Mr. Yarrow preferring to show that the contract speed could be realized with ease, rather than forcing the machinery to its utmost power. It

will be noticed that the mean of the two best consecutive runs—with and against tide—was over 27 knots.

Our readers will remember the experiments which Mr. Yarrow lately made with regard to the vibration of engines—an account of which appeared in a recent issue—and also his paper read before the Institution of Naval Architects on the vibration of steamers provided with excessive power. The trial of the *Havock* confirms conclusively the principles laid down, as we are informed no vertical vibration whatever was to be traced in any part of the hull at any speed. We may add that the speed during the three hours' run, calculated according to the usual formula, from the number of revolutions, showed a mean speed, as stated, of over 26 knots, in which was included numerous turns. These turns should be allowed as unfavorably affecting the speed of the boat, as they caused increased resistance. The bottom of the boat, also, had not been cleaned since the day she was launched, and in consequence was not in a condition to secure the best results. We remember in old days seeing boats at Poplar preparing for the next day's trial with a dozen or two of shoeblacks hard at work polishing up the bottom.

By the *Havock's* trial the Royal Navy is again placed in the very desirable position of owning the fastest vessel over tried in British waters, and we are pleased to be able to congratulate both the Admiralty and the contractors on this very satisfactory fact.

The *Havock* was again taken out on Friday, November 3d, for an eight hours' trial at an economical speed, with a view to ascertain the distance she would steam with the fuel supply she can carry on board, upon which depends her radius of action. It was found that, at a speed of 11.2 knots, the consumption was under ½ ton an hour, while at 10 knots it was 3½ cwt. an hour; and, as the bunkers have a capacity of 60 tons, it follows that the distance the *Havock* can steam without coaling is about 3,500 knots. The Admiralty authorities consider this new vessel a very great success in every respect. The *Havock* will now be provided with a few remaining fittings, and she is expected at Portsmouth the end of this month.—"Engineering."

H.M.S. *Speedy*.—The first official trial of the torpedo gunboat *Speedy* took place on October 3d. This vessel has been built and engined by Messrs. J. I. Thornycroft & Co., of Chiswick, and is especially interesting from the fact that she has Thornycroft water-tube boilers. The trial was with natural draft, and was for a period of eight hours. The results were of a highly satisfactory nature, over 500 horse power more than the guarantee being obtained. The speed of the vessel was 18.5 knots. The total mean indicated horse power was 3,043; the steam averaged 190 pounds pressure. The revolutions were about 209 per minute for the starboard engines, and 203 for the port engines.

On Tuesday, November 7th, the forced-draft trial was brought to a successful conclusion, and the last of the torpedo gunboats was thus added to the British Navy. The guarantee for the rest of this class has been 2,500 indicated horse power with natural draft, and 3,500 with forced draft. The *Speedy* was guaranteed for 4,500 forced draft. The contract was exceeded on both trials, no less than 4,674 indicated horse power being the mean on the 7th. The revolutions were 247 starboard and 243 port engine; the steam 193 pounds. The day was a bad one for the purpose, a strong northeast wind, which blew through the night and during the trial, making a nasty sea; the course being from the Nore to the North Foreland. The speed, however, was 20 knots, which could be considerably exceeded under favorable conditions. [A more extended notice of the trials of this vessel will be given in the next number of the JOURNAL.—Editor.]

Leda.—The official forced-draft trial of the first-class torpedo gunboat *Leda* was successfully carried out on the 11th September, off Sheerness, the dockyard being represented by Mr. Pattison, while Mr. Samuel Rock represented the Admiralty, and Mr. J. P. Hall the engineer contractors. This is the third of this class of vessels engined by Messrs. John Penn & Sons, Limited, and all have exceeded contract requirements. The engines were illustrated and described in "Engineering," vol. lv, page 280. The machinery is required to develop 3,500 indicated horse power with not more than 3 inches of air pressure in the stokeholds. The *Leda* obtained a mean of 3,601 horse power with an

average steam pressure in boilers of 148 pounds; vacuum, 27.5; revolutions, 246; mean air pressure in stokeholds, 2.21 inches. The speed of the vessel was 18.3 knots. The following details show the powers for the six half-hours as taken:

Half-hours.	Indicated horse power.		Collective indicated horse power.
	Starboard.	*Port.*	
1	1,783.9	1,763.8	3,547.7
2	1,771.8	1,811.2	3,583.0
3	1,777.6	1,784.4	3,562.0
4	1,937.1	1,854.5	3,791.6
5	1,801.9	1,767.1	3,569.0
6	1,784.5	1,769.6	3,554.1
Mean indicated horse power for the three hours,			3,601.2

The furnaces of the boilers, which are of the marine locomotive type, are corrugated on the sides and top on the principle of Mr. F. W. Webb, of the London and Northwestern Railway, and the fire-box ends of the tubes were fitted with ferrules on the Admiralty plan. On examination after the trials the boilers were found to have sustained no ill effects from the application of forced draft.

Renard.—The new first-class gunboat *Renard*, which was built and engined by Laird Brothers, of Birkenhead, was subjected to a full-power trial of her machinery at sea on Wednesday, the 6th of September. The trial was conducted under natural draft, and was of eight hours' duration, the results attained being considered very satisfactory. With a steam pressure of 143.6 pounds, and the engines working 219 revolutions per minute, a mean of 2,583.6 horse power was registered, with a speed of 17.6 knots. The vessel is preparing for her forced-draft trial.

FRANCE.

Dupuy de Lôme.—The armored cruiser *Dupuy de Lôme* has again had her trials stopped on account of an accident to her boiler. Mention of this accident was made in our last number, under the head of Dockyard Correspondence.

A singular misfortune seems to follow this magnificent ship and to defy the most perfect precautions. Her trials have now been in progress for nearly two years, and her engines and boilers have not yet fulfilled the requirements of the contract. The many attempts which have been made have always been stopped by singular and unforeseen accidents. On the last trial all was going beautifully, the engines were working remarkably well, when in coaling the furnaces the firemen discovered that two crown sheets had come down.

The boilers of the *Dupuy de Lôme*, built by the Chantiers de la Loire from a design made by the Navy Department, are of the fire-tubular Admiralty type, with two furnaces in each, built for a pressure of 160 pounds. The flues are of the Fox corrugated pattern, 51 inches in diameter and 0.669 inch (17 millimeters) thick, furnished by Fox & Company themselves, and are of mild steel. The metal is of excellent quality, for there is no evidence of a crack in the large collapsed portion in the furnace, although all trace of the corrugations has disappeared. This is fortunate, for otherwise the result might have been disastrous.

A cursory examination of the injured boiler revealed no local cause for the accident, there being no deposit of grease or salt sufficient to account for the collapse of the furnaces. If a more rigid examination should disclose nothing of the kind, it will have to be concluded that the furnaces are too weak. Calculated perhaps a little too closely, considering their large diameter and the high temperature and pressure which they have to sustain, the furnaces were very good as long as the metal preserved its original strength; but gradually, under the influence of successive heating, the metal became annealed to such a degree as to become too soft. These same furnaces, which gave way when the power being developed was only 10,800 horse power, successfully withstood the power test, in which the power developed was much greater, the engines at times developing as much as 14,800 horse power.

If our predictions should unfortunately be confirmed, it will be necessary either to change the boilers or, at least, to change or to reinforce the furnaces. In either case it will be necessary

to take out the boilers, and, consequently, to tear out a portion of the ship. The *Dupuy de Lôme* would then be out of commission for a year longer.—Translated from "Le Yacht," November 4, 1893, pages 412, 413.

D'Iberville.—On August 26th the torpedo cruiser *D'Iberville* was lauched at St. Nazaire, France. This vessel has been built from designs by M. de Bussy for the French Government, and, as the contract for her construction was fixed on 26th August, 1891, she has been just two years under construction. The vessel is of a new type, and measures 262 feet 2 inches in length by 26 feet 2 inches in breadth, with a displacement of 925 tons on a mean draught of water of 11 feet 1 inch. The propelling machinery is intended to develop 5,000 H.P., at about 265 revolutions per minute, and the estimated speed is 21.5 knots. The boilers and magazines are protected by a steel deck .65-inch thick. A powerful armament will be provided, including one 4-inch quick-firing gun, placed in the bow; three 2.5-inch quick-firing guns; four 1.5-inch machine guns, and four torpedo-launching tubes. The cost is expected to be about $575,000.

The *Lansquenet* will be the largest, and, for the present, the fastest of the French sea-going torpedo boats. She measures 165 feet 3 inches long by 15 feet 7 inches broad, and with a mean draught of 4 feet 2 inches will displace 138 tons. With twin screws and engines indicating 2,800 H.P., she is expected to attain a speed of 26 knots, or about 30 statute miles per hour. The cost will be about $104,000.

The *Charles Martel* was launched at Brest in September. She is a first-class battleship, the largest that has been hitherto built in France. She is 380 feet 6 inches long and 72 feet 1 inch broad, and with a draught of 27 feet 6 inches will displace 11,882 tons. Her engines will be of 13,500 I.H.P., and are expected to drive her at an extreme speed of about 17.7 knots. There are two screws. The belt armor, which is of steel, has a maximum thickness of 17.7 inches. The turret armor is 14.5 inches thick, and there is a protective deck of 2.7-inch steel. At each extremity is a turret, in which is mounted a single 11.8-inch 44-ton gun. On each broadside, sponsoned out so as to permit of fire

being delivered ahead or astern, is another turret, containing a single 10.6-inch 34-ton gun. On each broadside, in lighter turrets, are four 5.5-inch quick-firing guns, and in the upper works and tops are distributed four 9-pounders, twelve 3-pounders and eight smaller quick-firing or machine guns. There is provision for 800 tons of coal. The estimated cost of the vessel is $4,800,000.

The *Bugeaud*, a second-class protected cruiser of the largest type, was launched at Cherbourg in September. She is 308 feet long and 42 feet 6 inches broad, and with a draught of 20 feet 10 inches will displace 3,722 tons. Her engines, driving twin screws, will develop 9,000 H.P., and are designed to give an extreme speed of 19.2 knots. The steel deck is 2.4 inches thick. The armament will consist of six 6.2-inch quick-firing, four 3.9-inch quick-firing, eight 3-pounder quick-firing, and twelve 1-pounder machine guns, and six torpedo tubes will be fitted. The bunkers will carry 600 tons of coal. The total estimated cost of the ship is $1,270,000. She is a sister to the *Chasseloup-Laubat*, which is also being built at Cherbourg, and to the *Friant*, which is being built at Brest.

Jaurèguiberry. — The French battleship *Jaurèguiberry* was launched on Friday, October 27, from the yard of the Forges et Chantiers de la Méditerranée at La Seyne, near Toulon. The ship is 356 feet long by 72 feet 6 inches broad, and from the keel to the upper deck measures 47 feet 10 inches. The draught aft will be 27 feet 8 inches, and the displacement 11,820 tons. There are two triple-expansion engines, driving twin screws of manganese bronze. Steam is supplied by 24 groups of boilers of the Lagrafel-d'Allest type. With natural draft a total of 13,000 horse power is contracted for. This will give a speed of about 17 knots. With forced draft and a development of 14,200 horse power the speed should somewhat exceed 17.5 knots. The guns are arranged exactly as in the *Capitan Prat*, though they are, of course, of much heavier caliber. The main armament consists of four big guns, disposed lozengewise, each in a separate covered turret. Those on the quarterdeck and forecastle are each 11.8-inch 44-ton guns.

Those on the beams are on sponsons, and are each 10.8-inch 34-ton guns. All the other guns are quick-firing ones. On either side, a little astern of the forward turret and again a little forward of the after turret, is a small turret containing a pair of 5.4-inch 3-ton guns. In addition there are on the upper deck and superstructure and in the tops on the two military masts four 2.5-inch, twelve 1.8-inch and eight 1.4-inch guns. There are also six torpedo ejectors, of which two are submerged.

The armor includes a 17.7-inch end-to-end belt at and below the water line. This is brought down forward to the level of the point of the ram, and is surmounted by a belt of 3.9-inch armor, which protects the slope and edges of the armored deck. This deck, which is of steel, is 2.75 inches thick, and the armor of the large turrets is carried right down to it. The principal turret armor has a thickness of 15.7 inches. The 5.4-inch guns are behind 3.9-inch armor.

All the eight turrets are constructed upon M. Lagane's balanced system, and, no matter the direction in which they may be trained, the trim of the ship is not appreciably altered. The entire armor of the *Jaurêguiberry* will weigh nearly 4,000 tons, and will cost about $1,560,000.

The normal coal capacity is 800 tons, but it can be, if necessary, considerably increased. The complement will be 650 officers and men.

A remarkable feature of the *Jaurêguiberry* is the extensive use of electricity as a motive power. It will move the turrets, raise the ammunition, and do much other work, which, in the majority of modern ironclads, is done by steam or by pneumatic or hydraulic power. It will also, of course, light the vessel. The ship will contain 550 incandescent lights, and there will be six very powerful Mangin search lights. The total cost will, it is estimated, be about $4,500,000.

The following is a comparison of some of the leading details of the *Jaurêguiberry* with those of certain modern battleships of about the same displacement belonging to other powers :

	France. *Jaurèguiberry.*	England. *Nile, Trafalgar.*	United States *Iowa.*	Russia. *Three Saints.*
Displacement, tons	11,818	11,940	11,286	12,480
Length, feet	356	345	360	357.5
Beam, feet	72.5	73	72	72.1
Draught, feet	27.6	27.5	24	26.6
Indicated horse power	14,200	12,000	11,000	10,600
Extreme speed, knots	17.5	16.5	16.5	16.0
Guns	2—11.8 in.	4—13.5-in.	4—12-in.	4—12 in.
	2—10.8-in.	6— 4.7-in.	8— 8 in.	8— 6-in.
	8— 5.4 in.	8— 2.2-in.	6— 4-in.	4— 4.7 in.
	4— 2.5 in.	9— 1.8 in.	20— 2.2-in.	8— 2.2 in.
	12— 1.8-in.	7 mach.	6— 1.4-in	8— 1.8 in.
	8— 1.4 in.	.....	2 mach.	?
	6 tubes.	6 tubes.	7 tubes.	7 tubes.
Armor, inches:				
Belt	17.7	*20.0	14.0	16 0
Battery	3.9	*16.0	5.0	?
Turrets	15.7	18.0	15 0	12.0
Deck	2.7	3.0	3.0	2.7

* Partial and local only.

It is true that the weight of broadside of the *Jaurèguiberry* will be less than that of any of the ships with which she is compared. On the other hand, she is so arranged that she can fire two 11.8-inch, one 10.8-inch, four 5.4-inch, two 2.5-inch, six 1.8-inch, and four 1.4 inch guns simultaneously at any point on either beam, and can bring to bear upon any point ahead or astern one 11.8 inch, two 10.8-inch, and four 5.4-inch, besides smaller guns. In this respect, as well as in the important quality of speed and in general completeness of protection, she seems to be greatly superior to the other vessels.

CHILE.

Capitan Prat.—The following account of the voyage of the "*Prat*" from Toulon to Talcahuano Chile, was written by her chief engineer, Mr. Vial, and was first published in "La Union," a daily newspaper of Valparaiso, and is dated at Talcahuano, June 21, 1893.

For greater convenience the account is divided into four parts, the first one being devoted to a general idea of the voyage.

On the 12th of April last, while lying in Toulon, where the *Prat* was constructed, orders were received to prepare the ship for sea, and the following day the ship put to sea under two boil-

ers and laid her course for the island of St. Vincent, one of the Canary Islands.

During the early part of this run a full-speed test under these conditions was made, and a speed of eleven knots an hour was maintained for nearly six hours, the engines making sixty-five revolutions per minute.

April 22, ten days from Toulon, the *Prat* was spoken by a vessel of the Chilian government and ordered to return to Teneriffe, a distance of some 250 miles. At Teneriffe the bunkers were replenished, some 533 tons of coal being received.

From here to Bahia a speed of 10 knots an hour was kept up, and on the 12th of May the ship came to anchor in the last-named port, when 552 tons of coal were taken on board.

May 18 set sail for Punta Arenas, arriving there June 1.

During this passage the machinery was subjected to several trials, and the crew familiarized themselves with the ship, armament, &c.

From Punta Arenas the voyage was without notable incident, and on the 13th of June the *Prat* came to anchor in the harbor of Talcahuano.

The following table contains the results of the trial of May 21, one engine only being in use (in this test the port engine was employed, steam from all the boilers in use passing to this engine):

Revolutions of main engine, per minute	71
Throttle	.05
Cut-off	.42
Vacuum, 63 centimeters; inches	24.8
Boiler pressure, 8 kilogrammes; pounds	113.75
Engine pressure, 7 5 kilogrammes; pounds	106.65
Duration of trial, hours	12
Degrees of helm carried	8 to 10
Speed, knots	10 to 12
Coal consumed during 8 hours, tons	11.51
Coal consumed for 24 hours, tons	34.53

On the 23d of May a test was made of the capacity of the auxiliaries, and their ability to furnish circulating and feed water, as well as ventilation for the entire system.

The port auxiliaries were employed and performed their various duties satisfactorily.

As occasion offered, various tests, as has been already noted, were carried out, and all, without exception, were eminently satisfactory.

The boiler-feed system was ample, all pumps performed satisfactorily, and the evaporators furnished sufficient fresh water to supply all losses from these boilers during the entire voyage of more than forty days.

RÉSUMÉ.

The voyage was divided into four parts, as follows:

From Toulon to Teneriffe, days	10
From Teneriffe to Bahia, days	12
From Bahia to Punta Arenas, days	13
From Punta Arenas to Talcahuano	6
Total days actually at sea	41
The total coal consumed during the voyage was, tons	1,906
Distance steamed, knots	9,800
Total revolutions made	3,441,100

Translated by Chief Engineer H. Webster, U. S. N.

JAPAN.

Yoshino.—The cruiser *Yoshino*, built by Sir W. G. Armstrong, Mitchell & Co., Newcastle-on-Tyne, for the Japanese Government, was taken for her trial trip in the latter part of August. The vessel is 350 feet long, 46 feet 6 inches beam, with a displacement of about 4,000 tons. The armament of the vessel comprises four 6-inch quick-firing guns, eight 4.7-inch quick-firing guns, twenty-two 3-pounder quick-firing guns and five torpedo tubes. Four runs on the measured mile, with and against the tide, in accordance with the practice of the British Navy, were made under forced draft, when the actual speeds recorded were: First run, against the tide, 22.642 knots; second run, with the tide, 23.377 knots; third run, against the tide, 22.571 knots; fourth run, with the tide, 23.762 knots, the average speed being 23.03 knots. The engines, which have been constructed by Messrs. Humphreys, Tennant & Co., Deptford, worked throughout the trial without hitch of any kind.

MERCHANT STEAMERS.

Lucania.—In addition to the information already given about this vessel (vol. V, pp. 385–412) it may be mentioned that the bunkers have a capacity of 3,200 tons, and the average consumption on a voyage is stated to be 2,900 tons. The refrigerating machinery is on the ammonia compression system, with a capacity of 12 tons of ice per day.

The *Lucania* left Liverpool a few minutes after midnight on the morning of Sunday, the 3d of September, and ran in 10 hours and 47 minutes to Queenstown. That port was left in the afternoon of the same day, and Daunt's Rock, the timing point at one end of the journey, was abeam at 1·43 P. M. She was reported off Fire Island at 11 P. M. on the night of Friday, the 8th, making the passage to Sandy Hook in 5 days 15 hours and 37 minutes. This maiden passage was the best ever made. It greatly exceeds the record on the Southampton route made by the *Furst Bismarck*, and took about 18 hours out of that made by the *Campania*. But in justice to the latter it must be remembered that, when she started, the winter course of nearly 100 miles greater length was followed. The *Lucania's* daily runs on this remarkable passage (which barely escaped being an absolute "fastest on record") were 460, 490, 498, 516, 533, 284; distance, 2,781 miles; speed, 20.5 knots. The best day, 533 miles, is three miles better than the best done by any vessel except the *Campania*.

It should also be noted that the passage from Liverpool to New York was 6 days 4 hours and 10 minutes. This is an absolute record from Liverpool.

Nile.—The steamship *Nile*, which Messrs. James and George Thomson, Limited, Clydebank, have constructed for the Royal Mail Steam Packet Company's Southampton and South American mail and passenger service, went on her official speed trials

over the measured mile in Stokes Bay recently, and then proceeded on an eight hours' trial at sea, the results on both occasions exceeding expectations. The vessel is the largest yet constructed for the company in point of tonnage, and in determining her dimensions a departure has been made from present-day practice, in respect of fast steamers, as regards relation of breadth to length, more from the necessity for a specified cargo capacity than from choice. The practice is to increase the length of ships in proportion to their beam, with the view of obtaining higher speed while maintaining the cargo capacity; but, as the vessel was intended to trade with West India ports, as well as to Brazil and the River Platte, length was a somewhat restricted dimension, and it was determined to secure the required cargo space by increasing beam. In the vessels formerly built for the company—the *Clyde* and the *Thames*—the length was nine times the beam, but in the case of the *Nile* it is only eight times, notwithstanding which the speed was satisfactory. This gain in earning power, however, has brought about another change, for the *Nile* is the first of the modern steamers of the company without that clipper bow and little bowsprit which added so much grace to our old ships and to the early steamers. But all along the line utility is now the first consideration.

The overall length of the *Nile* is about 435 feet, and between perpendiculars 420 feet, so that she is 16 feet shorter than the *Thames* and *Clyde*, but has 2 feet more beam—52 feet, and the depth moulded is 35 feet 5 inches. The gross register tonnage is 6,050 tons, and at 21 feet draught the displacement is about 8,000 tons. In her construction strength has been a first consideration. The butts of all the shell plates, instead of being fitted with butt straps according to the usual method, have been overlapped and quadruple riveted. This adds materially to the rigidity of the structure. There are ten 'thwartship bulkheads, dividing the ship into eleven compartments, and these are carried up to the promenade deck, being stiffened by angles connected to the floorplates at the bottom of the ship, and to the various steel decks, by means of bracket plates. It is not infrequently regarded as sufficient to have one or two companion ways from

the state rooms below to the top decks—one forward and one aft—which is all right under ordinary circumstances; but in the event of the bulkhead doors in the passages having to be closed those occupying rooms on the decks below, in intermediate compartments, have no egress to the decks above. In the *Nile* this case is met in an interesting way. Portable galvanized iron ladders are bolted to the deck beams alongside of skylights arranged primarily for ventilating, and these ladders fold up against the deck when not required, but may be quickly swung down, when an easy way of escape to the deck above is required. The skylights insure not only ventilation, but a light to the passages.

Most of the first-class state rooms are arranged right fore and aft on either side of the ship on the main and upper deck, so that each has one or two large portholes, while the cabin bulkheads are fitted with jalousied panels. Right along the boiler and engine coamings are skylights which admit air and light down to the main as well as upper deck passages, and thence to the state rooms. These are sufficiently wide to afford egress to passengers to the upper deck. Forward and aft of these, special skylights and fanlights are provided, so that even in the tropics a sufficiency of air should find its way naturally into every part of the ship. The state rooms, which are unusually large, being 8 feet 3 inches by 10 feet, include in their equipment two folding lavatories, folding table, and two electric lights, as well as oil lamps in specially inclosed cases for emergency. The beds have all wire-woven spring mattresses. There is little difference between first and second class rooms, the latter being situated under the poop. Of first-class passengers 215 may be accommodated, and of the second 36, while 350 emigrants can be carried on the main and lower decks. The navigating officers' rooms are on the promenade deck in the vicinity of the engine coaming, which is carried right above the shade deck, and the engineers' rooms and petty officers' are on the upper deck.

The first-class saloons are forward, with the exception of the smoking room. On the promenade deck forward is the drawing or music room, panelled in satinwood and cedar, with a chastely-

designed stained glass cupola in the center, and sumptuously furnished and upholstered. There is an upright Bechstein piano, with satinwood frame, in the forward end, having on either side beautifully ornamented music cabinets. In the center of the saloon there is a well admitting light to the dining saloons on the upper and main decks below. This dividing of the *salle-à-manger* into two parts is common to all Royal Mail boats; and although it precludes the possibility of elaborate effort at effect, has the advantage of economizing room and insuring a more homelike feeling when a small complement of passengers is concentrated in one place, for, although not frequently, it does happen that vessels are not always crowded. In decorating the saloon the builders have very properly adopted bright wood and colors. The roof is in white, relieved with gold, while the panels between the numerous portholes on the forward end and on either side are of relieved scroll work in oak on a dull gold ground, the effect being to produce a well-lighted saloon. The main saloon accommodates 107 passengers at a large number of small tables, while in the saloon below 69 may sit, so that practically all the passengers may dine at the one hour. On the promenade deck there is, aft of the grand stairway, a ladies' private saloon. The smoking room is aft on the promenade deck, and is quite a cosy corner, panelled in walnut. From the room there is a companionway to the state rooms below, so that a passenger need not come into the open to get to any of the public rooms. The promenade deck, however, is sure to be appreciated in all weathers; the increase in the beam of the ship has increased its width, which is greater than on some of the largest Atlantic vessels; it is 140 feet long, being divided from poop and forecastle by wells which admit to two hatches. The promenade is completely sheltered by the shade deck above, and the view seaward is unobstructed.

To the shade deck has been fitted a series of electric lamps for illuminating the promenade in the evenings. The second class passengers have the poop deck for promenade, while on it is their smoking room, with dining saloon below. The promenade deck being carried on T irons above the upper deck, there is also

a large promenading space on either side of the latter. The deck and navigating machinery is most complete. The cargo is all worked by hydraulic gear, six cranes and two derricks having been provided by Brown, of Edinburgh, with an hydraulic winch for hoisting in the boats. While the davits are of the ordinary swivel type, the usual wooden chocks have been dispensed with for an effective arrangement by the builders, whereby the boat is released from both simultaneously by the operation of a lever giving a half-turn to a fore-and-aft rod, which throws down the support of the boat. The boats all rest on the shade deck. The windlass forward and steering gear aft have been fitted by Messrs. Napier Brothers, Limited. The latter has two high-pressure cylinders, which work the barrel, or can be quickly connected to work the screw gear in the event of the chains breaking. The valves of the steering engines are operated by an hydraulic telemotor placed in a wheelhouse immediately under, but operated from, the bridge. Hand gear has also been fitted aft. The light has been installed by the firm's electrical staff. The generating plant, situated on the floor of the engine room, is in duplicate, two high pressure engines being coupled direct to dynamos running at 210 revolutions, and producing a current of 100 volts at 165 ampéres. Each dynamo is sufficient to run 320 lights. There are in the ship 500. A large cold air chamber has been fitted in conjunction with Hall's plant.

The engines are of the triple-expansion inverted direct-acting type, and a feature of the engine room is the large area of floor space, due to the great beam of the ship, abundant passage room being also left at the back of the engines. The machinery may be said to be Thomson's standard type, the arrangement and details having been the result of the extensive experience of the management. The cylinders are 38 inches, 60 inches and 94 inches in diameter respectively, with a stroke of 5 feet 6 inches, while all the working parts are of Vickers steel, including the crank shaft. The frames, bed plate, &c., are of wrought iron. The tunnel shaft is also of malleable iron. The shafting throughout is of 19 inches diameter, and the thrust collars are of the ordinary horseshoe type. Brown's starting and reversing gear

is fitted to the engines, and the air and circulating pumps are worked from the high-pressure and low-pressure crossheads. Weir's installation, including feed pumps, feed heaters and evaporator, is fitted. Steam at 160 pounds pressure is supplied by four double-ended boilers, 15 feet in diameter by 19 feet long, with four furnaces in each end, making a total of 32. They have corrugated flues, which are 3 feet 3 inches mean diameter and 6 feet 6 inches long. The total heating surface is 17,300 square feet, and the grate area 650 square feet. There are three stokeholds, all with open hatchways, the boilers being arranged in pairs athwartship, each two having an uptake and funnel. There is in the after stokehold a donkey boiler for supplying steam for the auxiliary machinery in the ship.

The vessel is well finished, and presents a smart appearance, with her two funnels and three pole masts having just enough rake. The shade deck, with the boats above it, makes the vessel look high out of the water. She has certainly a high freeboard, which will tend to keep the broad promenade deck dry even in a heavy sea. At the trial recently, when representatives of the builders and owners, with a goodly company of guests, were on board, the sea-going qualities of the vessel were well tested, for a stiff breeze was blowing, reaching at times the velocity of half a gale. The measured mile at Stokes Bay was run six times, in alternate directions, and the wind was such as to interfere with the general result. Going to the westward it was on the port bow, and in the run in the other direction it was on the starboard quarter. The mean draught of the ship was 21 feet, the displacement being about 8,000 tons. The mean of the six runs indicated a speed of 17.099 knots, the horse power developed being 7,200 indicated horse power, the vacuum being 27 inches. There was plenty of steam throughout the run. On the following day, with a moderate breeze, the speed on an eight hours' run was 17¼ knots, with the engines working under normal conditions at 83 revolutions, and developing 7,700 indicated horse power. The highest speed attained during the eight hours' run was 17.69 knots. The *Nile* went on her first voyage on October 19, and was commanded by Captain

Spooner. The chief engineer is Mr. J. K. Ritchie, who has seen thirty years' service with the company, having started in the old paddle steamers working with steam at 10 pounds pressure.

Liguria.—On September 21st the Pacific Steam Navigation Co.'s steamer *Liguria* went down the Mersey on her official trial trip. She had been lately laid up in the Sandon Dock, where Messrs. David Rollo & Sons have converted the engines and fitted her with new boilers. The cylinders have been replaced by three new ones on the triple-expansion arrangement, and are 33, 54 and 88 inches diameter respectively, the stroke remaining as before, 60 inches. Each cylinder is fitted with a hard cast-iron liner, which also forms the jacket. The covers and bottoms of the cylinders are also jacketed, the supply steam being regulated by reducing valve, Auld's make. The drains from jackets pass into tanks regulated to show the water used. This arrangement is also fitted to the main steam at H.P. casing, also to the M.P. and L.P. casings, the condensed water being led direct to the feed tank, the supply from which is controlled by Weir's float arrangement. The pistons are of cast steel, and are fitted with compensating ring, carrying volute springs acting against the packing rings. Three new piston rods of mild steel have been fitted, the M.P. and L.P. having tail rods. The whole of the valve gearing has been removed, and an entirely new set of gearing has been fitted. The new gear is of much heavier design than the old, and is fitted with very large wearing surfaces. The gear is the ordinary double eccentric, double-bar link arrangement. It acts on the valve spindles direct in the case of the H.P. piston valve. The double piston valve in M.P. cylinder is connected by strong crossheads working in large guides. The L.P. valve, which is a Thom's patent slide, is placed at the back of the engines, and actuated through a cast-steel lever. A new propeller having four blades of manganese bronze has been fitted. The main feed pumps have been replaced with new of suitable size and design, the pumps and chests being best gun metal. These are worked from the main engines, but two very powerful auxiliary feed donkey pumps

are also fitted for boiler-feeding; these pump direct to the boilers, or through a Hocking's live-steam feed heater. The pumps, heater, evaporator, auxiliary condenser, and tanks are all placed in the passage, through the bunker, between engine and boiler rooms. The main boilers, which are fully up to the Board of Trade requirements for a working pressure of 180 pounds, are four in number, and are built of steel, being 14 feet 6 inches diameter by 17 feet long, double-ended, having 24 of Fox's patent corrugated furnaces. The whole of the floors, frames and reverse bars were gutted out of the boiler space, and a double-bottom ballast tank for fresh water, built in four compartments, having a bilge well at each end. Each compartment is fitted with the usual sounding, filling, air and signal pipes. The *Liguria* left the Morpeth Dock at 7 a. m. and proceeded down the river. After adjusting compasses, she made the run from the Bar Lightship to the Skerries and back, the engines running 72 revolutions, and giving 4,564 average I.H.P. The run was highly satisfactory, the average speed of the steamer being 16½ knots.

Cevic.—A new twin-screw steamer, which is by far the largest freight steamer in the world, was launched on Saturday, the 23d of August, from the yard of Messrs. Harland and Wolff, at Queen's Island, Belfast, and is intended on completion to take her place in the White Star cargo fleet. This vessel, which is named the *Cevic*—signifying her relation to the *Bovic*, *Tauric* and *Nomadic*—is of the following dimensions, viz: Length, 500 feet; breadth, 60 feet; depth, 38 feet; estimated registered tonnage, 8,315; gross, 5,335 net; total capacity of holds, 14,089 tons. She will be fitted for the accommodation of 800 head of cattle on the upper and bridge decks, and will in addition have permanent stalls for twenty horses in the center of the upper deck. The *Cevic* will be fitted with two complete sets of triple-expansion engines driving separate propellers, so that the chances of total breakdown will be reduced to a minimum, and every improvement that can be devised in respect of ventilation, fresh water supply, &c., conducive to the safe carriage of horses and live stock, will be provided. A ship of this large size, and so

completely equipped as the *Cevic*, should form an invaluable Admiralty transport for horses and material.

Roland.—The large steel screw-steamer *Roland*, which has been built for the Norddeutscher Lloyd, of Bremen, by Messrs. Sir W. G. Armstrong, Mitchell & Co., Limited, was taken out to sea on Wednesday, August 30, for her trial trip. The dimensions are as follows: Length, 357 feet; breadth, 44 feet, and depth, 28 feet 3 inches. The *Roland* is the pioneer ship of one of the Norddeutscher Lloyd's new departures, and is arranged for the transport of emigrants and cargo from Bremerhaven to New York. On the trial the *Roland* attained a speed of over 13 knots, which was considered extremely satisfactory, and the coal consumption, which was measured during five hours' continuous running at 12.25 knots, came out at 1.5 pounds per indicated horse power per hour. The machinery was supplied by the Wallsend Slipway and Engineering Company, Limited. A somewhat novel feature in the machinery department is the See ash ejector. A small hopper in the stokehold is connected to the ship's side above the water line by a gently sloping cast-iron pipe. At the bottom of the pipe a jet of water supplied by a pump furnishes a stream which rushes through the bottom of the hopper, through the discharge pipe, and out at the ship's side at an enormous velocity. The ashes are poured into the hopper and discharged through the side by the stream of water with such force as to throw them a considerable distance from the ship's side.

Bayern.—The North German Lloyd's mail steamer *Bayern*, which has just gone out from Southampton for China, has been lengthened to the extent of 50 feet, and her tonnage increased to 5,600 tons. The vessel was found too small for the eastern trade, and it was decided to lengthen her, and the ship was handed over to Messrs. Blohm & Voss, in Hamburg. She was placed in dry dock, and was severed amidships forward of the engine room. The fore part was drawn forward 50 feet by specially devised hydraulic gear, and a complete water-tight compartment 50 feet long built to connect the two parts, and

the necessary strengthening effected. The *Bayern* is now 450 feet long, and in the new part a main saloon was reconstructed, the other public rooms being rearranged and enlarged. The addition to the cargo-carrying capacity is 8,476 cubic feet, while a larger number of passengers may be carried. A sister ship, the *Sachsen*, is now being lengthened in the same way. Of course, many such lengthening operations have been carried out, the P. & O. Company having lengthened several of their boats in recent years, while the Union Company are having the *Moor* lengthened by Messrs. Thomson. Nevertheless this is another step forward of the German shipbuilders, for nothing of this nature on such a scale has hitherto been tried.

Valiant.—The twin-screw yacht *Valiant*, built for Mr. W. K. Vanderbilt by Messrs. Laird Brothers, of Birkenhead, sailed for America on Wednesday, August 16th, exactly nine months from the day on which the contract was signed.

The *Valiant* is by far the largest yacht in the world, being 2,400 tons register, and driven by engines developing 4,500 H.P., and her length is 312 feet. In addition to her engines the yacht carries two masts, square rigged, and capable of spreading a great area of canvas. Great care, almost secrecy, has been observed about the details of the vessel, but from the description given below it will be seen that she is fitted in the most luxurious style, and is one of the finest, as well as the largest yacht afloat. A fact remarked by many who saw her on her last trial trip was that she carried the British flag, and, therefore, her registered owners are British—a circumstance of some significance. The general fitting of the vessel is characterized by being "the best of everything," as an instance of which we may say that every hinge, bolt, catch and rail—excepting the awning rails—are of Wilson's white metal, a composition almost entitled to rank with the precious metals. Even the huge ventilators are constructed of this silvery alloy. In the matter of piping, equal excellence obtains, all the pipes for supply and waste, for hot and cold water, lavatories and sanitary appliances, are of the finest copper. Among other details the vessel is fitted with the electric light throughout, has patent signal-light indicators, steering gear, and

every possible improvement to date. Naturally, the cost has been enormous, and it is not improbable that Mr. Vanderbilt will have to expend the sum of at least £150,000 before he can call the vessel his own.

The designer of the hull is Mr. St. Clare Byrne, of Castle Street, a yacht architect who has achieved no little fame by reason of former designs. Mr. Vanderbilt himself has seen to most of the contracts, so that the actual builders of the ship have had less hand in her equipment than is usually the case. Paris, London and Liverpool have all been requisitioned for the decorative work, the leading firms in each city being entrusted with the various staterooms for embellishment. The actual construction of the deck houses was, of course, left to Messrs. Laird, who built all such first of iron and then an outside paneling of the finest teak, highly polished. The bulwarks, which are movable, are of similar construction, fine teak being about the commonest wood employed on any part of the *Valiant.* In fitting the rooms the builders have not had very much to do, but some beautiful figured teak, finely polished, embellishes the wall of the main companion way, which is really a grand staircase, the material appearing like fine olive wood. The pipe services, baths, &c., have been put in by Messrs. Laird, and no hotel ashore has a more complete system. Every hand-basin, bath or lavatory waste pipe is carefully trapped, all baths are of Stone's patent enamel on copper, and to every basin or bath is supplied a separate copper service of steam piping for cleaning each place by blowing out. The galleys are fitted with steam tables, ranges, and the most complete service of utensils, the pantries being similarily supplied. The men's quarters in the forecastle are fitted in teak, as are the servants' rooms also, there being bedrooms, bathrooms, and a servants' hall.

Taking the state rooms, there are about twenty, exclusive of the smoke rooms, dining saloons and library. The two latter, the largest apartments in the ship, are by Messrs. Cuael, of Paris. This saloon is 18 feet in length and 33 in width, running practically the whole breadth of the ship. The general design is Louis Quatorze, and the wood is fine grained French pine, re-

sembling English poplar, but, of course, the original grain and color of the wood is hidden beneath the fine white enamel, with its golden embellishments. The carving, which is out of solid wood, is simply exquisite, every foot of the wall paneling being rich in high relief carving, beautifully and artistically done. At one side of the hall is a Steinway piano, and the chair settees are of brass inlaid Chippendale. The furniture is upholstered in rich crimson silk velvet. The dome of the saloon rises to the upper deck, and is fitted with stained glass skylights. Leaving the saloon, a passage of about 100 feet in length, arched and beautifully decorated, and carpeted with a texture costing three guineas a yard—as are both the saloon and the library—leads to this latter apartment, where again the hand of the carver has had free play. This apartment is of dark walnut, unpolished; the panels and pilasters rich with the most beautiful carving, which, indeed, embellishes the entire apartment. The settees, sideboard, and general fittings are all of dark walnut, and overhead are beautiful panels of the same wood, with soft-tinted paintings. The fireplace and mantlepiece are the finest bits of work in the ship, being massive and exquisitely carved.

Mr. Vanderbilt's state room, by Messrs. Waring & Sons, is fitted up in a particularly luxurious style, the furniture being of richly-figured pollard oak, and consisting of a spacious wardrobe fitted with every conceivable accommodation. One corner of the room is fitted an ingle-nook fitment, the seats upholstered in rich cream ground and floral designed French silk, and above are cupboard and bookcases enclosed by doors paneled and fitted with beveled glass. Under and between the ports are seen a specially designed, very effective pollard oak cabinet or sideboard, an escritoire fitted with stationary appurtenances, bookcase, cupboards above, and a large lounge or settee, richly upholstered and covered with silk *en suite* with the ingle nook. The bedstead is made of pollard oak, with convenient cupboards below, the footboard paneled and carved and having a canopy headboard. The wall spaces, which are very limited owing to the fitments covering almost all, are paneled with the same silk as is used in the upholstery, and the ceiling frieze and beams are

covered with Tynecastle tapestry, decorated in a tone of ivory white. The carpet is a blue-shaded floral design Wilton, harmonizing with the tints in draperies. Adjoining this room, and approached through a pair of handsomely paneled and carved doors, is the bathroom and lavatory, fitted up and decorated in the most elegant manner.

Mrs. Vanderbilt's forward state room, ornamented by Messrs. S. J. Waring and Sons, is another exceedingly tasteful and elaborate apartment, the treatment of the detail in decoration and paneling revealing the choicest combination of coloring and delicate treatment. The ceiling, frieze and arches are covered with a special design of Tynecastle tapestry, decorated with a rich ivory white, the wall spaces being paneled with a light blue with stripe and floral design rich French silk. The fitments and furniture are of a very beautiful character, especial consideration having evidently been employed to produce so rich an effect. On one side is fitted an elaborate washstand. A large pedestal dressing table stands next to it and is fitted with numerous drawers, jewel-boxes, silvered beveled plates, &c. At one end of the room, facing the bedstead, is fitted an elegantly designed wardrobe. On the side and under the ports are fitted a large chest of drawers, a writing table and combination bookcase, and next is the bath, with a rising top richly upholstered, which acts as a lounge in the daytime. The bedstead is a perfect *objet d'art*, decorated in ivory white, as are all the other fitments in this room. It has a large footboard with richly carved panels, fluted pillars, and large drawers, the head end being a high circular canopy, draped with rich silk festoon valance, fluted headboard and top, festooned and tail draperies, &c. The ports are enclosed with enameled wood fitments, and draped with silk curtains *en suite* with bed. The carpet is a rich terra-cotta Wilton, harmonizing with the tints on the draperies.

Mrs. Vanderbilt's second bedroom at the after end of the ship is rich, but chaste in style—Sheraton enameled white and picked out with gold, the ceiling being of fibrous plaster, also enameled ivory white. All the furniture and equipments are thus tinted, and as the wall paneling and draperies are of an

old rose-color rich flowered silk, the effect is warm and soothing to a degree. A fine wooden bedstead is similarly enameled and draped, and the carpet is a beautiful gray Saxony, like all the after cabins and passages. Out of this room is a neat bathroom *en suite* with the bedroom, but with several wooden panels in place of draperies. The bath fittings are of the silver white metal, and the bath itself enameled copper. Going up from the main to the upper deck one finds Mrs. Vanderbilt's sitting room, a beautiful apartment in the old Adams style, the furniture, framings and casings being of dark mahogany, and the upholsterings and hangings of a peculiar green flowered silk, between apple and sage green in tint. The grate is an open one, the fire brasses and fenders having been designed to suit the general style of the room. The panels above the mantelpiece, and above a pretty little writing desk at one end of it, are fitted with Wedgwood plaques. The pilasters dividing the panels, and the whole of the mantelpiece, are beautifully carved; and Messrs. Gillow, of London, Lancaster and Liverpool, who have done these rooms, consider the deck room one of the best on the ship The apartment is about 16 feet square.

Miss Vanderbilt's room (also by Messrs. Gillow) is also very handsome, in the Cawthorne style of about a hundred years ago, the draperies being a peculiar blue and the ceiling a fine bit of Tynecastle work, with friezes of similar work.

The room for Mr. Vanderbilt's private secretary is fitted up by Messrs. Waring in richly figured Spanish mahogany, there being two spacious wardrobes fitted with drawers, trays, hanging compartments, and also a very compact dressing chest, with large silver beveled mirror; and for the secretarial duties a very elaborate writing cabinet is arranged, supplied with every necessary arrangement. The bath is cased in Spanish mahogany, paneled and moulded, and has a movable top upholstered in silk, arranged to act as a settee. The bedstead is similarly cased moulded and paneled, and a lavatory washstand is fixed at the bedside. The ceiling and frieze are covered with Tynecastle tapestry, decorated in a tone of ivory white, the walls being paneled with Tynecastle tapestry, subject panels and mahogany

enriched mouldings. The ports are enclosed with mahogany fitments, and draped with silk curtains.

The visitors' room is also fitted up in Spanish mahogany, and is a sumptuously appointed apartment, containing as it does a large cabinet or sideboard fitted with ranges of drawers, and a large washstand with cupboard. A range of cupboards, fitted with sliding doors and shelves, run under the ports with a specially-designed writing cabinet and bookcase, intervening, is next the bath, which is paneled and moulded in mahogany, and has the movable upholstered top for the purpose of a lounge. The ceiling frieze and beams are covered with Tynecastle tapestry decorated. The walls have a high mahogany dado, and the panels are filled with Tynecastle tapestry, decorated subject panels in enriched mahogany mouldings.

The captain's room, another of Messrs. Waring's works, is very finely appointed, fitted up in mahogany, and containing wardrobes, washstand, large chest of drawers, and dressing table fitted with silvered beveled mirrors. The bath is paneled and moulded with mahogany, and has an upholstered top, as before described. The whole of this work, also the furnishing of the officers' quarters, linens, &c., have been supplied by Messrs. S. J. Waring & Sons, Limited, and needless to say they have exerted themselves to the utmost, with the result that they have produced a most successful and eminently valuable addition to the field of furnishing and decorative art.

Messrs. Gillow are responsible for a fine social hall in the Francois I. style, the room being completely fitted in fumed oak with elaborate carvings, the coverings of the furniture and the draperies being of rich red damask. The general state rooms at the after end of the ship, which Messrs. Gillow have also done, are all pretty much alike in their elegance, but are draped in different colored silks or tapestries.

There is also a smoke room, by Messrs. Howard, London, who have put on some splendid paneling in Spanish mahogany, the room being at the fore end of the deck house, and so designed as to meet the wants and comforts of smokers.

The speed of the vessel is given at varying figures, but 16 knots

is most probably her rate of progression, although it has been stated that she has done 18.

The engine-room staff is about twenty all told, and the same number is approximately that of her deck crew.

The hull of the ship has been painted with Messrs. J. Dempney & Co.'s enameline anti-fouling composition. It is claimed for this composition that it is a thorough protection against rust, barnacles and all marine accumulations, while it does not blister under any temperature. After the yacht's bottom had been covered with this enameline it presented a smooth, glossy surface not unlike that produced by fine enamel.

The engines are triple expansion, driving twin screws; the cylinders are 23, 36 and 55 inches diameter and 36 inches stroke. There are two double-end and one single-end boilers having in all fifteen furnaces, and to work at 160 pounds. The electric installation is in duplicate and capable of supplying 310 lights. There is a refrigerating plant, as well as ventilating plant, steam steering gear, steam capstan, &c.

Under natural draft a speed of 15.5 knots was obtained, and a series of forced-draft trials over the measured mile at Skelmarlie gave slightly over 17 knots for the highest average of two runs, while the whole set of runs gave a little under 17 knots. During these trials the bunkers (containing 700 tons) were full of coal. The builders believe that when at average draught, she can make about 17.5 knots. A forced-draft trial of six hours was also made with the revolutions averaging 145, but the speed is not given.—"Marine Engineer."

Namouna.—Messrs. Fawcett, Preston & Co., Limited, of Liverpool, completed the refitting of Mr. James Gordon Bennett's yacht, the *Namouna*, in August, and the preliminary trials have been most successful, showing a performance considerably in excess of the contract speed. Messrs. Fawcett, Preston & Co., have supplied the following details of the engines and general equipment of the vessel, put in by them. The engines are of the triple-expansion type, with three cranks. The stokehold is closed and supplied with forced draft. The diameter of the high-pressure cylinder is 21 inches, of the intermediate 34 inches,

and of the low-pressure 55 inches, with a stroke of 30 inches. The crank shaft is 10-inches diameter; the air pump is 18 inches diameter, with 18-inch stroke; the bilge pumps (two in number), are 4 inches diameter, with 18-inch stroke. The surface condenser is fitted with 934 brass tubes, three-quarters inch diameter, having a total cooling surface of 2,353 square feet. The slide valves are placed on the front of the cylinders, and are actuated by single eccentric radial gear. Aspinall's governor is fitted to prevent excessive racing. A Weir's feed-pump is put in for supplying water to the boilers, and has a steam cylinder 9 inches diameter, pump 7 inches diameter, with a stroke of 21 inches. A Worthington Admiralty pattern vertical pump is used as an auxiliary feed to the boilers, and for general ship purposes, and has steam cylinders 6 inches diameter, 6-inch stroke, and pumps 4 inches diameter and 6-inch stroke. A centrifugal pump made by Messrs. Gwynne is provided for circulating cooling water through condenser, and the diameter of the suction and delivery pipes is 11 inches. The blowing engine for the forced draft has a fan 5 feet 6 inches diameter, 1 foot 10 inches wide, driven by Chandler's patent engine. A Quiggins' evaporator is put in, capable of supplying ten tons of fresh water per 24 hours, together with a Quiggins' feed-water heater and Harris' feed water filter. The propeller has a diameter of 10 feet 5 inches, pitch 15 feet with a surface of 37 square feet, and it is of a special design. Two boilers are 13 feet mean diameter, 10 feet 3 inches long, made entirely of steel, and are constructed to meet the requirements of the American Board of Supervising Inspectors and Lloyd's Register of British and Foreign Shipping for a working pressure of 175 pounds per square inch.

All the plates and the corrugated furnaces, it may be added, were manufactured in America. The sheet plates are 1 and 5-32 inches thick. There are three corrugated furnaces in each boiler, 3 feet 3 inches mean diameter, with 310 tubes 2½ inches external diameter in each boiler. The total heating surface in the two boilers is 3,508 square feet. The total grate surface is 117 square feet. During the sea trials and going with the tide the *Namouna* made 16½ knots per hour, whilst returning against

the tide the speed was 13¾ knots per hour, making an average speed of 15⅛ knots per hour, which, as the condition imposed by the owners was that the speed should not be less than 14 knots per hour, shows an excess of 1⅛ knots over the contract speed. In addition to the official trials, the *Namouna* had subsequently an opportunity of testing her speed against the *St. Tudno*, one of the quickest passenger steamers sailing out of the Mersey, and over the measured mile these two vessels kept even the whole of the distance, a very gratifying result to the captain, engineers and all concerned.—"Marine Engineer."

Marie Henriette.—On August 5th a fine new paddle steamer was added to the now popular mail service between Dover and Ostend. The last new addition, the *Marie Henriette*, built by the firm of Cockerill & Co., at Antwerp and Seraing, Belgium, made her official trials on the Clyde, and realized a mean speed during a continuous trial of four runs, between the Cloch and the Cumbræ Lights, of 22.2 knots per hour (the distance between the lights being 13.666 knots). The speed guaranteed by the builders was 21½ knots, with a heavy premium in their favor for extra speed, which they have secured to the extent of £4,000. The speed of the sister ship, the *Leopold II*, built in England, and tried at the same place, between the Cloch and the Cumbræ, was 21.995 knots; the *Marie Henriette* has, therefore, notwithstanding the unfavorable weather, surpassed this by one-quarter of a knot. The trial took place in the presence of the Belgian Government Commission, by which all the results were verified. The engines gave an I.H.P. of 8,200, with a pressure of 120 pounds of steam and 53 revolutions.

Gloucester.—The steamship *Gloucester* is the largest vessel in the Merchants' and Miners' line, being 293 feet over all, 42 feet moulded beam and 33 feet 2 inches moulded depth to the weather deck. She has four decks, and is remarkable for her breadth and depth, but her proportions are those which her owners have found most suitable for their business in their long and successful experience. She is otherwise of fine model, and has developed satisfactory speed qualities. She is built of steel throughout and her scantlings are fully up to the rigid require-

ments of the underwriters. The machinery consists of a triple-expansion engine, the cylinders being 28, 45 and 72 inches in diameter, with a common stroke of 48 inches, and turns a propeller 16 feet in diameter. She has four boilers, each 13 feet 9 inches in diameter, 11 feet 6 inches long inside, with 292 square feet of grate in twelve 45-inch furnaces. She has accommodations on the third and fourth decks to the extent of 56 state rooms. The saloon is on the third deck, 72 feet in length by 24 feet in width, and all elegantly finished in polished mahogany of exceptional beauty and design.

The *Gloucester* has a double electric plant of the Lundell system, each plant having full capacity for lighting the ship. There are 238 electric lights and a 2,000 candle-power search light. The running lights are also electric.

The trial trip took place recently in Chesapeake Bay, during which the run from the Lazaretto to Fort Carroll, a distance of $4\frac{1}{8}$ miles, was covered in exactly 16 minutes. The boiler at this time was furnishing steam at the maximum pressure of 165 pounds, and the engine was making 77 turns a minute, at full gear. So that the average speed on that spurt was 17.1 miles an hour.

The *Gloucester* made the run to Turner's Point, near Bay Ridge, some little distance below Annapolis, Md., and returned to Baltimore, occupying just five hours in a seventy-mile run, including all stops to adjust compasses, etc., also including the slow speed necessary in turning around to get headed down the river, and the reduced speed necessary to carefully navigate the crowded parts of the harbor.—"Seaboard."

Bangor.—The new steamer *Bangor*, of the Boston & Bangor Steamship Co., and the largest side-wheel steamer on the coast east of Fall River, was launched from the yard of Wm. McKie, at East Boston, on Thursday, October 26.

The new steamer is one of the two which Mr. McKie is building for this company, and is 266 feet long on the keel; over all, 280 feet; breadth of hull, 38 feet; breadth outside of guards, 66 feet; depth of hull, 14 feet 6 inches; tonnage, 1,600. The hull is divided into five water-tight compartments. The machinery

is being constructed by the W. & A. Fletcher Co., of Hoboken, N. J., from the drawings and designs of and under the superintendence of Mr. Stevenson Taylor.

Two steel boilers, built by the Atlantic Works, East Boston, 31 feet in length, shell 10 feet by 11½ feet front, will provide the power for a beam engine of 63-inch cylinder, 11-foot stroke and 1,600 horse power. She will have Morgan feathering wheels, 27 feet diameter and 10 feet face.

The dining saloon will be in the grand saloon forward. Above the grand saloon is the gallery saloon, extending all round the steamer, similar to the Fall River line boats. There are 186 state rooms and parlors finished in white and gold.

The steamer is to be heated by steam, and provided with General Electric Co. dynamos to supply 800 electric lights, steam windlasses, search lights, steam-steering gear and every convenience for the safety of passengers. She is to have a speed of 18 miles per hour.—"Seaboard."

City of Lowell.—A new twin-screw steel passenger steamer, the *City of Lowell*, designed for the Norwich and New York Transportation Company by A. Cary Smith of New York, is now being constructed at the Bath Iron Works, Bath, Maine, and will be placed on the route between New York and New London in the early part of 1894. Her principal dimensions are: Length of keel, 320 feet; length over all, 336 feet 1 inch; beam, moulded, 49 feet 6½ inches; beam, over guards, 66 feet; draught loaded, 13 feet; depth, main deck to keel, 20 feet 4 inches; tonnage, 2,400 tons.

The hull is constructed entirely of steel, with four complete transverse watertight bulkheads. She has five decks named respectively lower, main, saloon, gallery and hurricane, and all the work above the main deck, with the exception of the machinery and boiler hatch casements and also a few deck beams, which are placed for additional strength, will be of wood. The lower decks forward and aft are devoted entirely to the crew and free-berth passenger accommodation, there being ninety free berths foward and 102 aft, while forward of all the crew, deck hands and table waiters, sixty in number, are berthed also. About 200

feet of the main deck amidships are devoted exclusively to freight and are separated from the living spaces in all respects. On the after part of this deck is a commodious social hall, just aft of which is a hallway containing a handsome staircase, which leads to the saloon deck; also a gentlemen's washroom and comfortable quarters for the purser and freight clerk. Aft of all is situated the ladies' cabin containing six double-berth staterooms, twenty-seven free berths and the necessary wash rooms, etc. At the forward end of the deck is placed the Hyde patent steam windlass and the Williamson steam steerer. There is also berth accommodation for ten firemen and four coal passers on the port side, while the mess rooms, water closets, etc., for the crew are on the starboard side.

The saloon deck is devoted entirely to the accommodation of first-class passengers, and contains eighty-one double berth state rooms and twenty-five rooms with brass bedsteads. About amidships are the engine and boiler hatches, and the former is so arranged that the passengers can see right into the engine room and watch the working of the powerful machinery.

The dining room, kitchen and smoking rooms are on the gallery deck, and also thirty-five double berth state rooms. At the forward end is the pilot house, just aft of which and in direct communication are the state rooms for the pilot and captain. A large dining room then extends for sixty-eight feet the whole width of the deck, a stairway from here leading to the hurricane deck. The space around the engine and boiler hatches contains the café, officers dining room and state rooms. At the extreme aft end of this deck are the state rooms for passengers. A gallery or balcony is placed here, and a handsome staircase leads below to the saloon deck.

The propelling power consists of two independent sets of vertical inverted direct-acting triple-expansion engines, driving twin screws, the cylinders being 26, 40 and 64 inches diameter, respectively, with a common piston stroke of 36 inches. The engines have been designed by Charles E. Hyde, superintendent of the engineering department of the Bath Iron Works, a man well known by engineers as having designed and superintended

the construction of the first triple-expansion engine built on this continent. The boilers are six in number and of the Scotch return tubular type. Their length is 12 feet 10 inches and diameter 13 feet 6 inches. They are each fitted with three corrugated furnaces 43 inches in diameter, and are designed for a working pressure of 165 pounds to the square inch. The boilers are placed three on the starboard and three on the port side of a boiler room 44 feet long by 49 wide, and there are two oval smokepipes 9 feet by 7½ feet. The total estimated I.H.P. of the engines is, including all auxiliaries, 4,600, which with 125 revolutions per minute is designed to develop a speed of 20 knots, or over 23 miles per hour. The engines, boilers and coal take up 114 feet of the vessel's length amidships, the total coal bunker capacity being 90 tons, sufficient for the vessel to steam one round trip. The vessel is to be fitted with Horace See's patent ash apparatus and with Worthington pumps throughout.

The electric plant will consist of two units each including a large dynamo and 70 H.P. straight line engine. Each unit will be capable of lighting the entire ship, there being 700 lights, and also a powerful search light of the most approved pattern on the pilot house. The electrical plant will be placed in the main engine room and the dynamo and engine will be connected by a belt. The vessel will be fitted throughout with electric light fixtures from Page Bros. & Co. of Boston. The following boats will be carried: Six 22-foot metallic life boats; two 20-foot wooden boats, clinker built and square stern; one 15-foot wood dinghey, and two life rafts. The steamer's three anchors will weigh 2,800, 2,200 and 1,800 pounds respectively. She will have no spars. In every respect the *City of Lowell* seems likely to fulfill Mr. A. Cary Smith's prophecy, that she will exceed in power, speed, capacity and elegance any boat on the American coast.—"Marine Review."

El Primero.—This yacht was recently built by the Union Iron Works of San Francisco, and given a series of progressive trials in San Francisco Bay on August 11. The following particulars of the hull, engines and trials have been supplied by Irving M. Scott, Esq., vice-president of the works, and the data of the boiler by E. E. Roberts, Esq.:

Length on L.W.L., feet and inches	105–0
Length over all, feet and inches	137–0
Beam, extreme, feet and inches	18–0
Beam on water line, feet and inches	16–0
Depth, feet and inches	8–7
Draught, mean, feet and inches	4–7
Displacement, tons	73·48
Speed, miles	15

There is one triple-expansion engine, with cylinders 8, 12 and 20 inches diameter by 12 inches stroke.

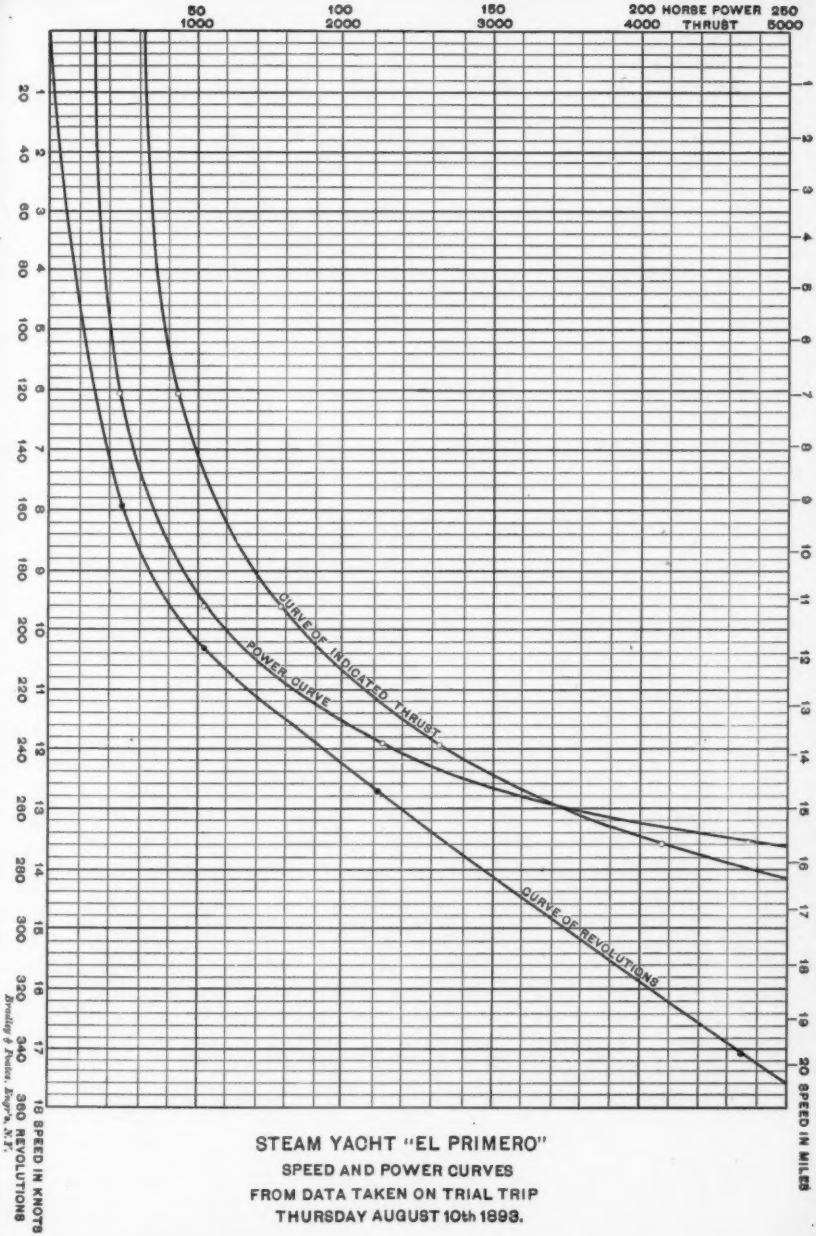
There is a Roberts boiler, No. 13, of which the dimensions are as follows:

Width over all, feet	7
Length over all, feet	8
Height from bottom of sediment pockets to top of jacket, feet and inches This does not include depth of ashpit, but there are about 6 inches vertical height between bottom of sediment pockets and top of grates.	6–2
Internal diameter of upflow coils, inches	1½
Internal diameter of feed coils, inches	1¼
Internal diameter of superheating coils, inches	2½
Internal diameter of downflow pipes, inches	5
Internal diameter of side pipes, inches, scant	5
External diameter of steam drum, inches	24
Thickness of steam drum, inch	7/16
Thickness of drum heads, inch	½
Heating surface in all upflow coils (external), square feet	576
Heating surface in both feed coils (external), square feet	367
Heating surface in both superheating coils and connections (external), square feet	92
Heating surface in both side pipes (external), square feet (figuring half circumference)	9
Heating surface in all downflow pipes (external), square feet (full circumference)	36
Heating surface in steam drum (external), square feet (full circumference)	40
Heating surface in both drum heads, square feet (total area)	6
Total heating surface in boiler, square feet	1,126
Total grate surface, square feet	35·33
Boiler, as weighed for freight by railroad company, net pounds	13,000
Calculated weight of water to steaming level, pounds	1,556
Total pounds	14,556

This weight includes casing, grates, firebrick, magnesia filling, and all small fixtures, but not smoke stack nor ashpan.

The screw propeller is 4 feet in diameter, 5 feet 6 inches mean pitch, and 7.00 square feet developed area.

On the progressive trials, given in the annexed table, the draught was 4 feet 2.75 inches forward, 4 feet 11.5 inches aft, 4 feet 7.12 inches mean; immersed midship section, 40.5 square feet; displacement, 71 tons. The length of the measured base was 2.1252 statute miles.



STEAM YACHT "EL PRIMERO"

SPEED AND POWER CURVES

FROM DATA TAKEN ON TRIAL TRIP

THURSDAY AUGUST 10th 1893.

STEAM YACHT *EL PRIMERO*.

PROGRESSIVE SPEED AND POWER TRIAL. SAN FRANCISCO BAY, AUGUST 11, 1893.

Runs.	Average mean pressures.			Mean pressure reduced to L.P. cylinder.	Average indicated horse power.				Revolutions.		Time on run.	Speeds.		Pressures.			
	H.P.	I.P.	L.P.		H.P.	I.P.	L P.	Total.	No. on run.	No. per minute.	M.—S.	Miles per hour.	Knots per hour.	Boiler.	1st receiv'r.	2d receiver.	Vacuum.
1st ...	22.5	5.8	1.52	7.62	10.9	5.57	4.61	23.08	1,715	159.	11'00	11.59	10.06	.....	.....	.....	.....
	.....	.....	.....	.....	.....	.....	.....	.....	3,764	.....	24'54	2.41	2.09	.....	.....	.....	.....
	22.5	5.8	1 52	7.62	10.9	5.57	4.61	23.08	.....	159.	.....	7.	6.076	160.	.....	.....	28.5
2d....	43.9	12.16	1.18	12.6	27.44	17.05	4.6	49.09	1,995	204.6	9'45	13.07	11.3	182.5	.....	.....	.....
	44.6	12.6	1.75	13.4	28.28	18.04	6.92	53.24	2,933	208.26	14'05	9.05	7.85	183.75	.....	.....	.....
	44.25	12.38	1.46	13.	27 86	17.54	5.76	51.16	.....	206.4	.....	11,06	9.6	183.12	.....	.....	28.5
3d....	59.	20.62	4 45	21.3	43 2	33.9	20.3	97.4	2,206	240.	8'25	15.13	13.13	184.5	.....	.....	.....
	60.9	22.08	5.97	24.4	50.45	41.09	34.92	126.46	2,793	271.8	10'16	12.41	10.7	186.	.....	.....	.....
	59.9	21.35	5.21	22.9	46.8	37.49	27.61	111.9	.....	255.9	.....	13.77	11.9	185.25	.....	.....	28.5
4th...	64.18	37.87	11.6	35.5	65.73	87.04	74.08	226.8	2,551	335.6	7 36	16.59	14.4	201.6	.....	.....	.....
	67.5	38.9	12.4	37.2	71.13	92.18	81.92	245.2	2,996	345.6	8'40	14.71	12.77	205.8	.....	.....	.....
	65.84	38.38	12.	36.3	68.43	89.61	78.	236.04	.....	340.6	.....	15.667	13.6	203.7	85.	12.	27.5

BOOK REVIEW.

RESISTANCE OF SHIPS AND SCREW PROPULSION.—By David W. Taylor, Naval Constructor, U. S. N. Published by Macmillan & Co., New York. Price, $3.75.

Mr. Taylor is already known to the readers of the JOURNAL as an original thinker and able writer, and, which is often of greater value, his writings are commendable for their power of exposition. His article in the JOURNAL of last November on Speed Trials was a complete treatise on the subject, and put matters so clearly that no one could go amiss.

The present volume will increase his reputation as an author, and will prove a valuable addition to the reference shelf of every student of marine propulsion.

He has availed himself of the works and experimental data of the Froudes and other leaders of the profession, and has added the result of his own researches.

Chapter I treats of resistance of submerged solids and of vessels without the complication of the propelling apparatus, and includes a discussion of the various methods for determining it, such as Rankine's and Froude's. Wave resistance, effect of shallow water, and squatting are also discussed.

Chapter II discusses the propeller apart from the hull, while Chapter III considers them together. Froude's blade theory is followed, although Rankine's is noticed and explained. The importance of the wake is shown, and its connection with negative slip.

Chapter IV treats of trials, and applies the principles set out in an elaborate analysis of the trials of the U. S. S. *Yorktown*.

Chapter V deals with the subject of powering ships, and gives all the usual methods, explaining their limitations. Special attention is given to the method by the Law of Comparison, and tables are given for reducing all vessels to a common standard

of 10,000 tons. In connection with these a series of curves for 10,000-ton vessels, at speeds from 13 to 25 knots, is given. Each diagram in the series is for a single knot on a large scale, so that the speed can be read to hundredths. The effect of rough weather and foulness of wetted surface are considered as affecting the calculations.

Chapter VI treats of propeller design for practical purposes, both as to size and strength. This chapter will be of special interest to engineers. The points in it are all clearly stated and most of them will be readily accepted. It is to be regretted, however, that some of the simple empirical methods, which are almost "rule of thumb," are not given. Every engineer who has investigated the matter is aware that excellent practical results are obtained by these methods. This does not mean that the elaborate method of the book is unnecessary; on the contrary it is of the highest value because it discusses every point which affects the efficiency. Unfortunately it involves a good deal of calculation, although Mr. Taylor has reduced this to a minimum by calculating tables which save much of the work.

The book is so good that it is hardly open to criticism. It may be observed, however, that the treatment throughout is largely mathematical, and while this doubtless is the proper scientific method and admirably adapted to students whose mathematical training is fresh, it makes it harder reading for older men whose devotion to practical work has prevented constant mathematical practice. The mathematics involved, however, are not difficult, and the results will repay the careful reading required.

Mr. Taylor is to be congratulated on his book, which will undoubtedly have a wide circulation.

HANDBOOK OF THE STEAM ENGINE, by Haeder and Powles.—While this work treats specially of land engines of moderate sizes, it will prove an interesting reference book for marine engineers. The plan of the work will be understood from an extract from the preface: "The present work aims at showing

the results of practical experince. Letter-press has been reduced as much as possible to allow of the introduction of numerous tables and drawings, these being the language of technical people."

There are nearly 1,100 illustrations in the book, and they cover almost every good design for each detail of the steam engine.

Tables are given for standard designs, showing the dimensions of details when the principal dimension is fixed, for example the thickness of the various parts of a piston of given diameter. There are also tables giving the weights of details and the aggregate for engine framing, cylinders, pistons, connecting rods, &c., of various sizes. Valves and valve gears for stationary engines are treated in great detail.

The work as it now appears is a translation of Mr. Haeder's book in German with additions, showing English practice by Mr. Powles. There are only a few examples of American practice.

It is to be regretted that the literary value of the book is not equal to the technical, and in future editions the letter-press might be revised with advantage.

For sale in this country by D. Van Nostrand Company, New York; W. H. Lowdermilk & Co., Washington, D. C. Price, $3.00.

PRACTICAL INSTRUCTIONS FOR USING THE STEAM ENGINE INDICATOR.

The Crosby SteamGage and Valve Company has just published with the foregoing title a handy pocket-book of 95 pages, which will prove valuable to all users of steam engines. It is primarily intended to advertise the Crosby indicator, and gives a complete description of that instrument.

Besides this, however, it contains information on reducing motions, precautions in attaching the indicator to secure accuracy, the use of the planimeter, the Barrus throttling calorimeter, &c. It is unfortunate, in the description of the reducing motions, that nothing is said as to the inaccuracy of the "slotted lever" gear,

nor the proportions for a "pendulum and link gear" to secure accuracy. In the methods for computing the mean pressure the plan of using a long slip of paper on which the ordinates are laid down in succession, so that only one measurement is needed, is given, but attention is not called to the fact that greater accuracy is secured than where each of ten or twenty ordinates has to be measured by the scale.

The second section of the book has been prepared by Mr. Albert F. Hall, S.B., of the Blake Pump Co., and contains a great deal of useful information expressed very simply and clearly. This part explains the generation of steam, distinguishing between the two latent heats, Rowland's valve of the mechanical equivalent of heat, the conduct of engine and boiler tests, and computation of results. There are many little hints which are of great practical value, and which will be appreciated at once by the experienced engineer.

The book has been prepared with a view to easy comprehension by users of the indicator who have not had the advantage of a technical education, so that the style may seem very elementary to trained engineers. Even they, however, will find it a handy work of reference.

The book is for sale by the Crosby Co., 93 Oliver street, Boston.

CONTINUOUS CURRENT DYNAMOS AND MOTORS. By Frank P. Cox.—New York: The W. J. Johnston Company, Limited, 41 Park Row (Times Building), 1893. 271 pages, 83 illustrations, Price $2.00.

This work, intended for students, gives the theory and design of continuous-current dynamos and motors as understood and practiced in the designing room, and the methods of testing described are those of the factory testing room. The practical side of various questions treated is always kept in view, discussions having little bearing in this direction being excluded, as well as the descriptions of different machines and systems which are so often used to pad out the pages of similar treatises.

The first four chapters consist of a brief review of the electrical units and the general principles of the machines, and may be considered as an introduction to the subsequent portions; the higher branches of mathematics have been avoided here, as elsewhere. Chapter V is on calculations pertaining to the magnetic circuit. Chapter VI treats of the theory of windings, losses, etc., and Chapter VII of the special points to be observed in motor designing.

In Chapters VIII, IX, and X the application to the design of armatures, field magnets, and motors of the principles developed in the preceding chapters is explained by reference to numerical problems selected, so as to cover as broad a field as possible, and show in what manner to make the various compromises always necessary in practical designing.

In Chapters XI and XII the methods of testing a completed machine and investigating its characteristics and the effect of various changes in design and operation are very fully discussed and illustrated by numerous curves.

As the subject of the steam engine is so closely allied to the testing and operation of dynamos and motors, the last two chapters are devoted to indicator diagrams and steam power calculations, which are treated in the same practical manner as the purely electrical subjects.

The four appendices are on tests of irons, ampere-turn tables, determinations of sizes of wire for armatures and field coils, and on the calculation of belting.

With one exception, all of the engravings were specially prepared for this work, and almost all of the numerous curves are reproductions of those obtained in actual commercial tests.

STANDARD TABLES FOR ELECTRIC WIREMEN, by Chas. M. Davis. Fourth edition, thoroughly revised and edited by W. D. Weaver. Flexible morocco, 128 pages. Price, $1.00.

The third edition of this popular work was exhausted within a few months after its issue, and the fourth edition has been delayed in order that it might contain the latest revisions of the In-

surance Rules of the Underwriters' International Electric Association, now almost exclusively used in the United States. In addition to the above rules there has been added to this edition an important section on the calculation of alternating current wiring which, for the first time, brings this subject within the reach of practical men.

A number of the most important tables were prepared expressly for this work, and, being copyrighted, cannot be found elsewhere. Among these are the tables of alternating-current wiring coefficients, those on limiting currents for exterior wiring and on the candle power of arc lamps, and the table enabling the ones for the three standard lamp voltages to be used for any voltage or drop, as well as several others, including a complete set of wiring tables calculated on a uniform basis of 55-watt lamps.

The method of determining the sizes of conductors for incandescent wiring enables feeders, mains and branches to be proportioned as nearly exact as desired instead of only approximated to as by other methods. The wiring formulæ for motor circuits, etc., are put in a simple and most practical form so as to be easily applied by any one. The formulæ for horse power of engines and boilers are published here for the first time, and while they are based on rational principles, the different values of heating surfaces in boilers being considered, the results they give are the actual commercial ratings and not the theoretical horse power.

OBITUARY NOTICES.

JAMES HENRY FITTS.

The many friends of Prof. Fitts were shocked to hear of his death in a railroad accident, July 24th, 1893, while on his way to Chicago to attend the International Engineering Congress, where he was to have read a paper on a recent invention of his, an evaporative surface condenser.

He was born in Mecklenburg county, Virginia, January 27th, 1861, and entered the Naval Academy as a Cadet Engineer in 1878, a member of a class noted for its ability, and in which he always held high rank. Graduating in 1882, he served two years at sea in the North Atlantic Squadron, and was commissioned an Assistant Engineer in June, 1884.

He resigned from the Navy in August, 1884, to accept the chair of engineering and physics in South Kentucky College, where he remained until 1886, when he became Professor of Mechanical Engineering in the Virginia Agricultural and Mechanical College, at Blacksburg. Here his earnest work and ability brought the school of engineering to a high degree of efficiency.

Prof. Fitts was a lovable man, one of those kindly, generous souls, whose presence is a benefit and encouragement to all about them. Both in the service and out of it, he was a general favorite.

He leaves a widow, *née* Miss Mary M. Blair, of Richmond, Va., and two little sons.

EMIL FLACH.

A life full of promise was prematurely ended by the death of our esteemed associate, Emil Flach, on the 2d of September, at Mörsil, Sweden.

At the time of his death Mr. Flach was not quite thirty years of age, but his studious energy, his clear intellect, and strong

manly character had aroused expectations that he would attain pre-eminence in his profession.

After graduating from the college at Upsala, in 1883, he entered the Royal Polytechnic Institute at Stockholm in 1884, from which institution he graduated with honor in 1888.

He served an apprenticeship at the works of the Stafsjö Engineering and Gun Manufacturing Company, but found employment later with the Bergsund Ship and Engine Building Company, Stockholm. Practical sea service was to a certain extent received on two Swedish steamers, the *Motala* and the *Bergsund*. Not satisfied with what could be learned in his own country, he sought wider fields of experience in the employ of the Maxim-Nordenfelt Gun and Ammunition Company, London, England. The attractions of the United States for his energetic mind and mechanical tastes were too strong to allow of his remaining in England.

His next step was a visit to this country, where he became connected first with the Columbian Iron Works at Baltimore, and later with the Pennsylvania Steel Company at Sparrows Point, Md.

In July, 1890, Mr. Flach entered the service of the U. S. Government as a draughtsman in the Bureau of Steam Engineering, Navy Department, where he won the friendship of his associates and esteem of the officers in charge. Commodore Melville, who highly appreciated his ability, recommended Mr. Flach for the responsible position of Chief Draughtsman for the S. L. Moore & Sons Co., Elizabeth, N. J. This position he held until appointed representative from Sweden to be present at the experiments made with the John Ericsson Submarine Gun.

This commission he fulfilled satisfactorily and made an elaborate report to the Swedish Government.

In November, 1892, Mr. Flach was tendered the position of Assistant Engineer with the Swedish Salvage Co. "*Neptune*." He was at once detailed to the work of raising H. M. S. "*Howe*," sunk at Ferrol, Spain, upon which new duties he entered with his characteristic spirit and push.

Not satisfied with the reports from the divers, Mr. Flach himself went "below" to examine the work, and in doing so overtaxed his strength and contracted the malady which ended his life a few weeks later.

A few days before the *Howe* was successfully raised, Mr. Flach was obliged to go on the sick list, greatly to his chagrin, thus losing the opportunity of taking part in the final work of lifting the ship and enjoying the following festivities.

At the first symptoms of lung troubles Mr. Flach was transferred to H. M. S. *Seahorse*, where all possible care was taken to restore him to health, but when no signs of improvement appeared it was decided to send him to the Marine Hospital in Plymouth, where he was a patient up to the first part of June, when he had improved sufficiently to be taken to his home in Sweden.

He was yet very feeble, but it was supposed that the high mountain air in the north of Sweden would be beneficial. With this hope in view he was installed in the sanatorium at Mörsil, but to no avail; his overtaxed constitution could not resist the insidious attacks of the disease which ended his life.

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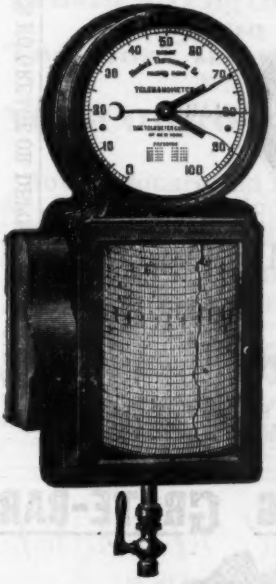

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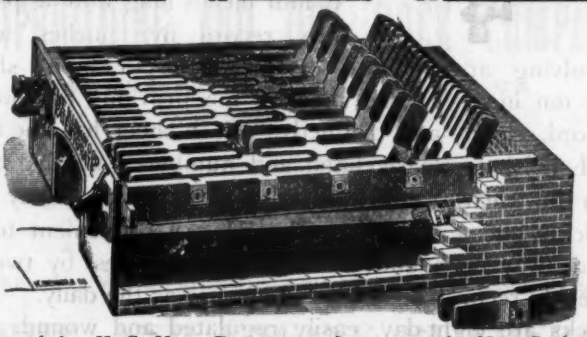

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